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BY THE

REV. DAVID BLAIR,

AUTHOR OF A GRAMMAR ON CHEMISTRY, UNIVERSAL PRECEPTOR, &C. &C.

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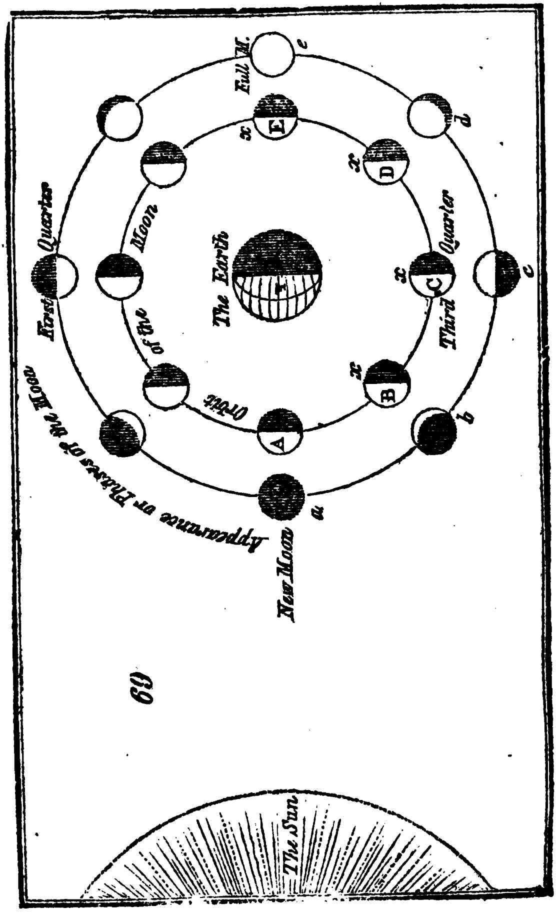

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A

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Author of the Class Book, Universal Preceptor, English Grammar, Reading Exercises, Models of Letters, &c.

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FROM THE AUTHOR'S

PREFACE

TO THE TWELFTH LONDON EDITION.

THE Author of the following pages is aware that there already exists several valuable but expensive books on Natural and Experimental Philosophy; and he should not have presumed to add to their number, except for the purpose of reducing an important branch of knowledge, in bulk and price, to the level of the business of schools, and adapting the whole to the present state of knowledge.

Every instructor of youth must be aware, that mere disquisitions are of no use in the art of teaching; and that no science can be taught, if the student does not *work* or perform operations in it; or answer *questions* which involve the consideration of its various details.

He who only reads *about* a science, can be nothing more than a *smatterer;* whilst he who commits its terms and elementary principles to memory, and applies them by some act of his own mind, to the various combinations of the science, soon becomes a *master* of it.

In strict conformity with this principle, this Grammar of Natural Philosophy has been compiled. All the definitions and elementary principles have been written with studied brevity, so that they may be learned by rote. With these have been intermixed such easy and familiar Experiments, Observations, and Illustrations, as will enable the young student to *work* in each science, while at the same time COPIOUS QUESTIONS have been annexed, for the purpose of adapting the book to the system of teaching by questions without answers.

The author cannot let pass this favourable opportunity, to express his sense of the honour which has been rendered to his humble endeavours, in the five works which he has already submitted to the public. He alludes to his CLASS BOOK, his UNIVERSAL PRECEPTOR, his EXERCISES IN READING, his ENGLISH GRAMMAR, and his MODELS OF JUVENILE LETTERS, in all of which he laboured diligently to give a popular feature to useful knowledge, and has met with his reward in the unparalleled success of those books.

He hopes this new and improved edition of the Grammar of Natural Philosophy, will not diminish the reputation he has acquired, and that, combined with the QUESTIONS, it will be found to be the most complete course of Philosophy, that has ever been submitted to Schools.

JULY, 1820.

A
GRAMMAR
OF
PHILOSOPHY.

OF MATTER AND ITS PROPERTIES.

1. MATTER is the general name of every thing or substance, that has length, breadth, and thickness.

Obs. Philosophers have in all ages discussed the general nature of matter, but without arriving at any satisfactory result. This is certain, that all we know of matter is merely relative to our own powers and senses; and those relative properties, being all we can know, are the proper objects of Philosophical inquiry.

2. The properties of all matter or substance, are SOLIDITY, DIVISIBILITY, MOBILITY, and INERTNESS.

3. *Solidity* is that property which every substance possesses, of not permitting any other substance to occupy the same place at the same time.

Illustration 1. If a piece of wood or metal occupy a certain space, before any thing else can take possession of that space, the wood or metal must be removed.

2. Water and even air, have this property.

Experiment 1. If some water be put into a tube closed at one end, and a piece of wood be inserted that fits the inside of the tube very accurately, it will be impossible by any force to get the wooden piston to the bottom of the tube, unless the water is first taken away.

2. The experiment may also be made with air instead of water.

Corollary. Therefore water, air, and all other fluids, are, with reference to space, equally solid with the hardest bodies.

4. *Divisibility*, is that property of matter, by which its parts may be divided and separated from each other. Of this division there can be no end.

Illus. 1. Since matter can never be annihilated by division, so we can never imagine it to be cut into such small particles, that any one of them shall not have an upper and under surface, which may be separated, if we have instruments fine enough for the purpose.

2. It would also be absurd to say, that the greatest mass has more halves, quarters, or thousandth parts, than the smallest particle of matter.

Exp. 1. If a grain of gold be melted with a pound, or 5760 grains of silver, and a single grain of the mass be dissolved into diluted nitric acid, the gold, which is only the 5761st part of a grain, will fall to the bottom and be visible; but the silver will be dissolved in the acid.

2. A grain of gold may be hammered by the gold-beaters to such a degree of fineness, that the two millionth part of the grain may be seen by the naked eye.

3. In addition to these experiments we may observe, that there are animalcule so small, that many thousands of them taken together, are smaller than the point of a needle. Mr. Leewenhoeck informs us, that there are more animals in the milt of a codfish, than there are men on the whole earth, and a single grain of sand is larger than four millions of these animals. Moreover, a particle of the blood of one of these animalcule has been found, by calculation, to be as much smaller than a globe of the 1-10th of an inch in diameter, as that globe is smaller than the whole earth.

4. The *natural* divisions of matter are still more wonderful. In odoriferous bodies, a surprising subtilty of parts is perceived: several bodies scarcely lose any sensible part of their weight in a great length of time, and continually fill a very large space with odoriferous particles. Dr. Keill has computed the magnitude of a particle of assafœtida to be only 38 trillionths of a cubic inch.

Corol. From all which it is evident, that matter is actually divisible to a degree much greater than we can imagine; and to which divisibility we can set no limits.

5. *Mobility* is that property of matter by which it is capable of being moved from one part of space to another.

Illus. It is found from experiment and observation, that all matter is capable of being moved, if a sufficient force can be applied for the purpose.

6. *Inertness*, or inactivity, is that property of matter by which it would always continue in the same state of rest or motion, in which it is put, unless changed by some external force.

Illus. 1. It is evident that matter, as a stone, can never put itself in motion, unless it be in some way acted upon.

2. Bodies in motion, as a bowl on the ground, or a cannon-ball passing through the air, fall from motion to a state of rest, either by the friction of the earth, by the gravity or weight of the body, or by the resistance of the air.

Exp. 1. A marble shot from the fingers would run but a small distance on a carpet: its motion would be continued much longer on a flat pavement; and longer still on fine smooth ice. Here the friction is greatest on the carpet, and least on the ice. If the friction were quite removed, and the resistance of the air also, the marble once put in motion would continue in that state for ever

2. If a ball were fired from a cannon with a certain velocity, and there was no resistance from the air, it would circulate round the earth perpetually, and never come to a state of rest.

3. If a person were standing in a boat at rest, and the boat be suddenly pushed from the shore, he will be in danger of falling backwards. And if the boat in swift motion be stopt before he is aware, he will fall forwards, because his tendency will then be to continue in the same state of motion.

QUESTIONS ON MATTER AND ITS PROPERTIES.

What is *matter?*
What are the properties of matter?
What is *solidity?*
What is *divisibility?*
Give an example of the divisibility of matter.
What is *mobility?*
In what does this property of matter consist?
What is *inertness?*
What effect does inertness have on matter?
Why does not a body once put in motion always continue to move?

OF THE MECHANICAL AFFECTIONS OF MATTER.

7. By Attraction is meant the tendency that bodies have to approach each other whatever be the cause of such tendency.

8. There are five kinds of attraction : viz. the attraction of *cohesion ;* of *gravitation ;* of *electricity ;* of *magnetism ;* and of *chemical affinity.*

9. The attraction of *Cohesion* is that by which the constituent particles of bodies are kept together. By this principle they preserve their forms and are prevented from falling to pieces.

Illus. The attraction of cohesion takes place between bodies or atoms, only when they are at very small distances from each other.

Exp. 1. If two leaden bullets are scraped very clean, and squeezed together, they will adhere so firmly as to require a considerable force to separate them.

2. If two globules of quicksilver, be placed near each other, they will run together and become one large drop

The result of sundry experiments made by professor Musschenbroek, to shew the *cohesive power* of different solids, may be seen in the following table In estimating the absolute cohesion of solid bodies, he applied weights to separate them according to their length ; the pieces of wood which he used were parallelopipedons, each side of which was 27-100ths of an inch, and the metal wires made use of were 1-10th of a Rhinland inch in diameter, and they were drawn asunder by the following weights.—

	lb.		lb.
Fir	600	Copper	299 1-4
Elm	950	Brass	360
Alder	1000	Gold	500
Oak	1150	Iron	450
Beech	1250	Silver	370
Ash	1250	Tin	49 1-4
Lead	29 1-4		

10. *Capillary* attraction is reckoned a species of cohesion. The suspension of the fluid in capillary tubes, is

owing to the attraction of the ring of glass contiguous to the upper surface of the fluid; and in capillary tubes, the heights to which the fluid rises are inversely as the diameter of the bores.

Exp. 1. If a small glass tube open at both ends, be dipt in water, the water will rise in the tube, higher than its level in the basin. The smaller the bore of the tube, the higher will the water rise.

2. Take two pieces of glass five or six inches square, join any two of their sides, and separate the opposite sides with a small piece of stick, so that the surface may form a small angle; then immerse them about an inch deep in a basin of coloured water, and the water will rise between the glasses and form a beautiful curve.

3. A piece of sugar or sponge, will draw up water or any other fluid upon the same principle.

11. It is, probably, owing to the various degrees of cohesion, that some bodies are hard, and others soft; that some are in a solid, others in a fluid state.

Obs As it is by the attraction of cohesion that the parts of a body are kept together; so when a body is broken, it is this attraction that is overcome. Hence the reason of soldering of metals, gluing of wood, &c. Hence also may be explained why some bodies are *hard*, others *soft*, and others *fluid*, which properties may result from the different figures of the particles, and the greater or less degree of attraction consequent thereupon. *Elasticity* may arise from the particles of a body, when disturbed, not being drawn out of each other's attraction; as soon, therefore, as the force upon it ceases to act, they restore themselves to their former position.

12. *Repulsion* is a force that is supposed to extend to a small distance round bodies, so as to prevent them from coming into actual contact.

Obs 1. The repelling force of the particles of a fluid is but small, and, therefore, if a fluid be divided, it readily unites again. But, if a hard substance, as glass or sealing wax be broken, the parts cannot be made to adhere, unless they are moistened in one instance, or melted in the other.

2. Sir Richard Phillips who ascribes *attraction* to bodies mutually intercepting the impulse of a universal medium, acting through all space, ascribes *Repulsion* to vortices of eddys in the circumambient medium, produced by those peculiar causes

which always accompany high degrees of repulsive action. The repulsion of electricity he considers as merely relative; because every electrified surface has within a given distance a contrary electricity, and light bodies when apparently repelled from one surface, are, in truth, but attracted by the other surface; and perhaps all repulsion is produced by a counter-attraction.

Exp. 1. Water repels most bodies till they are wet. A small sewing needle will swim in a basin of water.

2. Drops of water will roll on the leaves of many vegetables without wetting them.

3. If a ball of light wood be dipped in oil, and put into a pan of water, the water will be repelled from the wood, and will form a channel round it.

13. The attraction of *Gravitation*, or *gravity*, is the name of that force by which distant bodies tend towards one another.

Obs. 1. All bodies on or near the surface of the earth tend towards its centre by a power called *the attraction of gravitation*, or according to the writer above mentioned, by *intercepted pressure of an elastic medium*, which fills all space, and seeks to pervade all matter; and this seems a reasonable cause of the phenomenon. *Monthly Mag. Oct.* 1811.

2. A stone, or other heavy body let fall, will move towards the earth till it meet with some other body to obstruct its course. And bodies move in lines perpendicular to the surface, because the point to which they ultimately tend is the centre of the earth, and the line of direction produced coincides with the radius, and is at right angles with the surface, which is nearly spherical. Some bodies ascend, because they are acted upon by a force greater than the attraction of gravitation, and in a contrary direction. Vapours, smoke, &c. do not descend, because they are *lighter* than the air, and supported by it.

3. When we speak of *attracting powers*, we do not attempt to explain their nature or assign their causes. Having derived general principles or laws of nature, from phenomena, we only give a name to these principles, in order to explain other appearances by them.

4. The tendency of all bodies towards the earth really results from their tendency towards the several parts of the rth. For, by an experiment made by Dr. Maskelyne upon e side of the mountain Schehallien, he found the attraction that mountain sufficient to draw the plumb-line sensibly om the perpendicular. *See Hutton's Dictionary.*

14. By gravity, a stone dropped from a height falls to the surface of the earth; and by it the heavenly bodies are retained in their orbits.

15. The planets gravitate towards the sun, and towards each other, as well as the sun towards them.

16. By gravity all terrestrial bodies tend towards the centre of the earth, and in all places equally distant from the centre of the earth, the force of gravity is equal.

Obs. See the Monthly Magazine, May 1, 1813, for an account of the effects of *Pressure* of all terrestrial substances on each other; the above writer observes, that the power of PRESSURE acts from the surface to the centre of all planets, or independent totalities of matter NECESSARILY and WITHOUT INTERMISSION: and is, or has been, the great instrument or HANDMAID of NATURE, by which most of its VARIETIES of substance are, or have been produced. It is synonymous with the action or momentum of the *weight* of bodies in their endeavour to fall to the centre of planetary spheres, and with the impulse called by astronomers the *principle of gravitation.* It is evidently one of the primary principles of nature, and would drive all atoms of matter into solid and immoveable contact, but for another power called REPULSION, synonymous to elasticity, or expansion, producing varied degrees of density. To *press* and to *resist* appear to be the conflicting principles or agencies, to which we may ascribe all the phenomena of nature; and in the degree in which pressure overcomes resistance, or resistance counteracts pressure, heavy and light bodies, inert minerals, or active organizations, become the accidents, or necessary varieties, of those active powers. To PRESS and to RESIST appear then to be the active principles of all matter, or in other words, UNION by *gravity*, and EXPANSION by *heat*, seem to be the great secondary causes of all phenomena. The ELASTICITY of a universal medium producing action from *without* and substantial COMPRESSION *towards* a centre; and the ELASTICITY of heat producing action from *within* and EXPANSION *from* its respective centres, point out ELASTICITY as the generic moving power of Nature. And if Elasticity and its synonyme expansion, be a mere result of HEAT, and HEAT itself be merely a phenomenon of *motion*, then it would appear that MOTION itself, is the primary cause of all things! Nor is there any incongruity in referring to the same primary cause, the PRESSURE of gravity, and the EXPANSION which opposes gravity, because the elasticity of the medium of space producing gravity is *universal*, and the elasticity producing expansion, is but *local* and *relative*."

17. The force of gravity is less at the equator than it is at the poles, because the equatorial diameter is 24 miles longer than the polar diameter, and because the swing, or centrifugal force of the earth at the equator, diminishes the gravity.

Obs. Hence, seconds' pendulums, which in this latitude must be 39,2 inches, require to be 1-10th shorter, or but 39,1 at the equator.

18. The force of gravity is greatest at the earth's surface, from whence it decreases upwards and downwards. It decreases upwards as the square of the distance from the centre, and downwards simply as the distance.

Obs. 1. The power of gravitation is greatest at the surface of the earth, from whence it decreases both upwards and downwards; but not in the same proportion. The force of gravity *upwards*, decreases as the *square of the distance* from the centre. That is, gravity at the surface of the earth, which is about 4000 miles from the centre, is four times more powerful than it would be at double the distance, or 8000 miles from the centre. Gravity and weight may be taken in particular circumstances, as synonymous terms. We say a piece of lead weighs a pound, or sixteen ounces, but if by any means it could be carried 4000 miles above the surface of the earth, it would weigh only 1-4 of a pound, or four ounces; and if it could be transported to 8000 miles above the earth, which is three times the distance from the centre that the surface is, it would weigh only 1-9th of a pound, or something less than two ounces.

2. It is demonstrated, that the force of gravity downwards decreases, as the distance from the surface increases, so that at one half the distance from the centre to the surface, the same weight, already described, would weigh only 1-2 a pound, and so on.

Thus, a piece of metal, &c. weighing, on the surface of the earth, one pound, will at

at	The centre weigh - - -	0
	1,000 miles from the centre, -	1-4 pound.
	2,000 " " - -	1-2
	3,000 " " - -	3-4
	4,000 " " - -	1
	8,000 " " - -	1-4
	12,000 " " - -	1-9th

And at the distance of the moon from the earth, which is 240,000 miles, it would weigh only the 3,600th part of a pound, because the distance is 60 times further from the centre of the earth than the surface.

QUESTIONS ON THE MECHANICAL AFFECTIONS OF MATTER.

What is meant by *attraction?*

How many kinds of attraction are there?

What is *cohesive* attraction?

What parts of bodies are affected by this kind of attraction?

What effect does it have on solid bodies?

Define what is meant by *capillary attraction?*

What is the rule in regard to the rise of fluids in capillary tubes?

How may this kind of attraction be illustrated?

What effect does the various degrees of cohesive attraction have on bodies?

What is the cause of *elasticity* in bodies?

What is *repulsion?*

Does this force act strongest in solids, or fluids?

What simple experiment will show that bodies repel each other?

What is *gravity*, or *the attraction of gravitation?*

To what point do bodies tend by this attraction?

What is the cause of this power?

What does the experiment of Dr. Maskelyne prove?

Is there any difference in the gravity or weight of the same body at different places, and why?

Why is it necessary that seconds' pendulums should be shorter at the equator than at the poles?

Where is the power of gravitation greatest?

In what proportion does it vary upwards, or downwards from the surface of the earth?

What would be the weight of a pound of metal here, when carried to the distance of the moon?

THE LAWS OF MOTION.

19. Motion is the continued and successive change of place of any body. Nothing can be produced or de-

stroyed without motion, and every thing that happens depends upon it.

20. Primary Laws of Motion are,

First, *That every body will continue in its state of rest, or of uniform motion, in a right line, until it is compelled by some external force to change its state.*

Secondly, *That the change of motion is always proportional to the moving force by which it is produced, and it is made in the line of direction in which that force is impressed.*

Thirdly, *That action and re-action are always equal and contrary.*

21. We are chiefly concerned with two kinds of motion.

1. That by which an entire body is transferred from one place to another.

2. The motion of the parts of bodies among themselves, supposed to be the cause of fluidity and vapour.

Illus. By the *first* kind of motion, a heavy body falls to the surface of the earth, a carriage moves, and a ship sails. By the *second*, plants and animals grow, and the compositions and decompositions of bodies take place.

Exp. Take a decanter of clear water, and hold it in the rays of the sun, and you will see that the light particles contained in it are in perpetual motion.

2. Let the rays of the sun pass through a small hole in a window shutter, and you will observe the particles floating in the atmosphere are in constant motion, of whose existence you were not before aware.

22. Several things require notice with regard to motion:

1. The force which impresses the motion.
2. The quantity of matter in the moving body.
3. The velocity and direction of motion.
4. The space passed over in the moving body.
5. The time employed in going over this space. And
6. The force with which it strikes another body that may be opposed to it.

23. Every body, by its inertness, resists all change of state; therefore, to put a body in motion, there must be sufficient cause.

Obs. Any body at rest on the surface of the Earth will always continue so, if no external force be impressed upon it to give it motion, and if the obstacle which hinders the attraction of gravitation from carrying it towards the centre be not removed. A body being put into motion by some external impulse, if all external obstructions were removed, and the attraction of gravitation suspended, would move on for ever in a right line; for there would be no cause to diminish the motion, or to alter its direction. This cannot be fully established by experiment, because it is impossible entirely to remove all obstructions; but, since the less obstruction remains, the longer motion continues, it may be reasonably inferred, that if all obstacles could be removed, motion once communicated to any body, would never cease.

Illus. 1. It is plain that a mass of matter, as a stone, cannot put itself in motion; it therefore would have for ever remained at rest, unless acted on by some power.

2. When a cannon ball is first discharged, it may be said to move in a straight line; and it is plain, that this would always be its direction, unless some power turned its course. It is also as evident, that it would always continue its motion forward, did not the friction of the air, or its own gravity, or some other cause so impede its motion, as to bring it to the ground.

24. The causes of motion are called motive powers, and are called muscular or mechanical: as the action of men and other animals, the force of wind, water, gravity, the pressure of the atmosphere, or any elastic medium, and steam.

25. The change of motion produced in any body, is proportional to the force impressed, and in the direction of that force.

Obs. Effects are proportional to their adequate causes. If, therefore, a given force will produce a given motion, a double force will produce the double of that motion. If a new force be impressed upon a body in motion, in the direction in which it moves, its motion will be increased proportionable to the new force impressed: if this force acts in a direction contrary to that in which the body moves, it will lose a proportional part of its motion; if the direction of this force be oblique to the direction of the moving body, it will give it a new direction.

26. To every action of one body upon another, there is an equal contrary *re-action;* or mutual actions of bodies on each other are equal and in contrary directions, and are always to be estimated in the same right line.

Obs. Whatever quantity of motion any body communicates to another, or whatever degrees of resistance it takes away from it, the acting body receives the same quantity of motion, or loses the same degree of resistance, in the contrary direction: the resistance of the body acted upon producing the same effect upon the acting body, as would have been produced by an active force equal to, and in the direction of, that resistance. Hence it appears, that one body acting upon another, loses as much motion as it communicates; and that the sum of the motions of any two bodies in the same line of direction, cannot be changed by their mutual action.

27. The velocity of motion is estimated by the time employed in moving over a certain space, or by the space passed over in a certain time. The less the time, and the greater the space moved over in that time, the greater is the velocity.

Illus. 1. *To ascertain the degree of velocity*, the space run over must be divided by the time.

2. *To measure the space run over, the velocity must be multiplied by the time;* for it is evident, that if either the velocity or the time be increased, the space run over will likewise be increased.

3. If the velocity be doubled, then the body will move over twice the space in the same time: if the time be twice as great, then the space will be doubled: but if the velocity and time be both doubled, then will the space be four times as great.

Exam. 1. If a ship sail at the rate of 12 miles in an hour, or sixty minutes, then the velocity is equal to one mile in five minutes.

2. If two persons set out together on a journey, and one walks two miles and a half, and the other walks five miles, an hour, the velocity of the latter, will be double that of the former.

28. A body in motion must every instant tend to some particular point. In which case the motion will be in a t line, or it may be continually changing the point

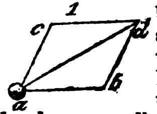
to which its motion is directed; and this will produce a curvilinear, or circular motion.

29. If a body is acted upon only by one force, or by several forces in the same direction, its motion will be in the same direction in which the moving force acts.

Exam. The motion of a boat, which a man at a given place draws to him with a rope, is of this kind.

30. Equable motion is either simple or compound. *Simple* motion is that which is produced by the action, or impressed force, of one cause. *Compound* motion is that which is produced by two or more conspiring powers, i. e by powers whose directions are neither opposite nor co-incident.

31. If two or more forces, differently directed, act upon the same body at the same time, as it cannot obey them all, it will move in a direction somewhere between them. This is called *the composition and resolution of motion.*



Illus. Suppose a body *a* to be acted upon by another body in the direction *a b*, while at the same time it is impelled in the direction *a c*, then it will move in the direction *a d*. If the lines *a b*, and *a c*, be made in proportion to the forces and the lines *c d*, and *d b*, be drawn parallel to them, so as to complete the parallelogram, then the line which the body *a* will describe, will be in the diagonal *a d*, and the length of this line will represent the force with which the body will move.

Exam. 1. There are many instances in nature, of motion produced by several powers acting at the same time. A ship driven by the wind and tide is one: so also is a paper kite, acted upon by the wind in one direction, and by the string in another.

2. A ball fired from a cannon is acted upon by two forces, the one is that occasioned by the powder, the other is the force of gravity.

32. The force, or power of overcoming resistance, in any moving body, is as its momentum, or quantity of motion.

Obs. Since a body having a certain degree of motion is able to overcome a certain degree of resistance, it is manifest, that with an increased momentum, it will be able to overcome a greater resistance. Hence the momentum of any body is

33. In moving bodies, if the quantities of matter be equal, the *momenta*, or quantity of motion, will be as the velocities.

Obs. If the body A be equal to the body B, but A has twice the velocity of B, A has twice as much motion as B.

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Obs. If the bodies *a* and *b*, fig. 1. move with equal velocities, since every portion of matter in *a* has as much motion as an equal portion of *b*, it is evident, that if *a* has twice the quantity of matter of *b*, it must have twice as much motion.

35. The momenta of moving bodies, are in the compound ratio of their quantities of matter and velocities.

Obs. The greater quantity of matter there is in any body, and the greater velocity it moves with, the greater will evidently be its quantity of motion, and the reverse. If, for example, the body A be double of the body B and moves with twice its velocity, the momentum of A will be quadruple of that of B: for it will have twice the momentum of B from its double quantity, and also twice the momentum of B from its double quantity of matter. Hence, if in two bodies, the product of the quantities of matter and velocities are equal, their momenta are equal, or as the products.

QUESTIONS ON THE LAWS OF MOTION.

What is *motion?*

What are the primary laws of motion?

What are the several things to be noticed in regard to motion?

What are the causes of motion?

How do moving bodies gain a new direction?

What is meant by *reaction ?*

How is the *velocity* of motion estimated?

What is the rule for ascertaining the degree of velocity?

What is the rule for measuring the space run over?

What is understood by *simple* and *compound* motion?

What is understood by the *composition* and *resolution* of motion?

How is this kind of motion illustrated?

What proportion is there between the force or power of a moving body, and its momentum?

Illustrate this law.

What proportion do the *momenta* of moving bodies bear to their velocities?

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When are the momenta of moving bodies equal?

OF ACCELERATED MOTION.

36. *Accelerated* motion is that in which the velocity is continually increasing from the continued action of the motive power. *Uniformly accelerated* motion, is that in which the velocity increases equally in equal times.

Illus. 1. The increasing velocity with which a body falls to the earth, is an instance of accelerated motion, which is caused by the constant action of gravity.

2. A cannon ball is acted on by a single impulse of the powder and the accelerating force of gravity, it therefore describes a curve. This is the foundation of the art of gunnery.

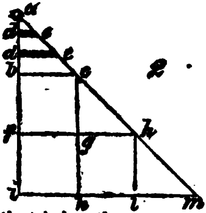
37. A new impression being made upon a falling body, at every instant, by a continued action of gravity, and the effect of the former still remaining, the velocity continually increases.

Illus. Suppose a single impulse of gravitation, in one instant, to give a falling body one degree of velocity; if after this the force of gravitation were entirely suspended, the body would continue to move with that degree of velocity, without being accelerated or retarded. But, because the attraction of gravitation continues, it produces as great a velocity in the second instant, as in the first; which being added to the first, makes the velocity in the second instant, double of what it was in the first. In like manner, in the third instant, it will be tripled; quadrupled in the fourth; and in every instant one degree of velocity will be added to that which the body had before; that is, the motion will be uniformly accelerated.

38. Motion is said to be *retarded*, if its velocity continually decreases; and to be *uniformly retarded*, if its velocity decreases equally in equal times.

Obs. The student who has not learnt some Algebra and Geometry, may go to Article 40 without disadvantage.

39. The velocities of falling bodies, are in proportion to the spaces run over, and the spaces passed over in each instant, increase as the odd numbers 1, 3, 5, 7, 9, &c.



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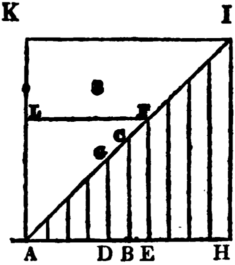
It follows, that the *whole* space described, is as the square of the time; that is, in twice the time, it will fall through four times the space; in thrice the time, nine times the space, &c.



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Obs. All bodies descending in vacuo, are found to fall through 16.1 feet in one second, and to acquire a velocity in falling which would carry them uniformly through 32.2 feet in the next second, and an increase of velocity, equal to this, found to be added to every succeeding second of time.

2. In the first instant there is one space run through; at the end of the second, there are four; at the end of the third, nine; and so on.

40. It has been found by experiment, that a body falling from a height, moves at the rate of about 16 feet in the first second of time; in the next 48, in the third 80, in the fourth 112 feet, and so on.

Exam. The space will therefore be 16 in the *first* second; 16+48, or 64 equal to 16×4: 4 being the square of 2, in the *second* second; 16+48+80, or 144 equal to 16×9: 9 being the square of 3, in the *third* second: 16+48+80+112, or 256 equal to 16×16; 16 being the square of 4, in the *fourth* second. And so on, because 4, 9, 16, &c. are the squares of 2, 3, 4, &c.

41. The *force* with which a body moves, or which it exerts upon another body, is always in proportion to its *velocity* multiplied by its weight, and this force is called the *momentum* of the body.

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Exp. 1. If two equal cannon-balls be projected by different quantities of powder, so that the velocity of the one is double that of the other, then the force or momentum of the former will be double that of the other.

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QUESTIONS ON ACCELERATED MOTION.

What is *accelerated* motion?
What is meant by *uniformly* accelerated motion?
What causes acceleration of motion?
Why does a ball shot out of a cannon describe a curve?
When is motion said to be *retarded*?
Demonstrate the laws of falling bodies by a diagram.
What laws do falling bodies observe in a vacuum?
At what rate are the velocities of falling bodies increased?
What is the rule for estimating the force of a moving body?
Illustrate this rule.

um of space producing gravity is *universal*, and the elasticity producing expansion, is but *local* and *relative*."

17. The force of gravity is less at the equator than it is at the poles, because the equatorial diameter is 24 miles longer than the polar diameter, and because the swing, or centrifugal force of the earth at the equator, diminishes the gravity.

Obs. Hence, seconds' pendulums, which in this latitude must be 39,2 inches, require to be 1-10th shorter, or but 39,1 at the equator.

18. The force of gravity is greatest at the earth's surface, from whence it decreases upwards and downwards. It decreases upwards as the square of the distance from the centre, and downwards simply as the distance.

Obs. 1. The power of gravitation is greatest at the surface of the earth, from whence it decreases both upwards and downwards; but not in the same proportion. The force of gravity *upwards*, decreases as the *square of the distance* from the centre. That is, gravity at the surface of the earth, which is about 4000 miles from the centre, is four times more powerful than it would be at double the distance, or 8000 miles from the centre. Gravity and weight may be taken in particular circumstances, as synonymous terms. We say a piece of lead weighs a pound, or sixteen ounces, but if by any means it could be carried 4000 miles above the surface of the earth, it would weigh only 1-4 of a pound, or four ounces; and if it could be transported to 8000 miles above the earth, which is three times the distance from the centre that the surface is, it would weigh only 1-9th of a pound, or something less than two ounces.

2. It is demonstrated, that the force of gravity downwards decreases, as the distance from the surface increases, so that at one half the distance from the centre to the surface, the same weight, already described, would weigh only 1-2 a pound, and so on.

Thus, a piece of metal, &c. weighing, on the surface of the earth, one pound, will at

at	The centre weigh			0
	1,000 miles from the centre,			1-4 pound.
	2,000	"	"	1-2
	3,000	"	"	3-4
	4,000	"	"	1
	8,000	"	"	1-4
	12,000	"	"	1-9th

And at the distance of the moon from the earth, which is 240,000 miles, it would weigh only the 3,600th part of a pound, because the distance is 60 times further from the centre of the earth than the surface.

QUESTIONS ON THE MECHANICAL AFFECTIONS OF MATTER.

What is meant by *attraction?*

How many kinds of attraction are there?

What is *cohesive* attraction?

What parts of bodies are affected by this kind of attraction?

What effect does it have on solid bodies?

Define what is meant by *capillary attraction?*

What is the rule in regard to the rise of fluids in capillary tubes?

How may this kind of attraction be illustrated?

What effect does the various degrees of cohesive attraction have on bodies?

What is the cause of *elasticity* in bodies?

What is *repulsion?*

Does this force act strongest in solids, or fluids?

What simple experiment will show that bodies repel each other?

What is *gravity*, or *the attraction of gravitation?*

To what point do bodies tend by this attraction?

What is the cause of this power?

What does the experiment of Dr. Maskelyne prove?

Is there any difference in the gravity or weight of the same body at different places, and why?

Why is it necessary that seconds' pendulums should be shorter at the equator than at the poles?

Where is the power of gravitation greatest?

In what proportion does it vary upwards, or downwards from the surface of the earth?

What would be the weight of a pound of metal here, when carried to the distance of the moon?

THE LAWS OF MOTION.

19. Motion is the continued and successive change of place of any body. Nothing can be produced or de-

any given time; for this number is as the velocity with which the body moves.

46. The centripetal forces of equal bodies revolving in equal circular orbits, are inversely as the squares of their periodical times.

Obs. The circular orbits or spaces being equal, the times in which these are described, or the *periodical times*, are inversely as the velocities; and therefore, the squares of the periodical times are inversely as the squares of the velocities, or the squares of the velocities are inversely as the squares of the periodical times; but the centripetal forces are as the squares of the velocities; therefore, these forces are inversely as the squares of the periodical times.

47. The centripetal forces of equal bodies, revolving in unequal circular orbits, if the periodical times are equal, are as the radii of the circles.

48. The centripetal forces of equal bodies, revolving in circular orbits, are as the radii of the orbits, or distances, directly, and as the squares of the periodical times inversely.

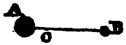
Illus. If the periodical times are equal, and the radii unequal, the force is as the radii. If the radii are equal, and the periodical times unequal, the forces are inversely as the squares of the periodical times. Therefore, if both the radii and periodical times are unequal, the forces will be in the compound ratio of both, or as the radii directly, and the squares of the periodical times inversely.

OF THE CENTRE OF GRAVITY.

49. The *centre of gravity* of a body, is that point, about which all its parts do in any situation exactly balance each other, so that if a body be suspended or supported by the centre of gravity, it will rest in any position.

50. Whatever supports the centre of gravity bears the weight of the whole body; therefore, the whole eight of a body may be considered as balanced in this oint.

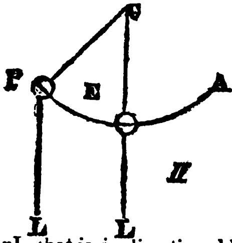
51. The common centre of gravity of two or more bodies, is the point upon which they would rest in any position.



Illus. If the centres of gravity of two bodies, AB. fig.3. be connected with the right line AB, the distances AC, and BC, from the common centre of gravity, C, are inversely as the weight of the bodies A and B; that is, the point of C will be as much nearer to A than to B, as A is heavier than B; that is AC : BC :: B : A.

Exp. Suppose A to be a ball of 12 pounds, and B to weigh only 4 pounds, and the length of AC to be five inches: then BC will be 15 inches: for it will be 5 : BC :: 4 : 12, or 4 X BC=5X12=60, and BC=20-4=15.

52. The centre of motion is the point about which the body moves; and a heavy body suspended on a centre of motion will be at rest, if the centre of gravity is directly under, or above, the centre of motion.



Illus. If a heavy body E, fig. II. hangs by a string on a centre of motion C, the action of gravitation at E is in the direction EL, contrary to the direction in which the string acts to prevent the body from falling. In this position, therefore, the opposite forces being equal in contrary directions, destroy each other, and the body is at rest. But if the body is at *p*, one of the forces acts in the direction *p*C: and the other in the direction *p*L, that is, in direction oblique to each other, whence the body will move in the diagonal of the parallelogram formed by *p*C, *p*L. And in all cases, since (without the aid of mechanical powers afterwards explained) the force which sustains any body must be equal to its weight, the centre of gravity can only be at rest when these forces are in the same line of direction, that is, when the centre of gravity is directly under, or directly above the centre of motion.

53. If a line be drawn perpendicular to the horizon, from the centre of gravity of a body, it is called the *line of direction*, because it is the line which the centre of gravity would describe if the body were suffered to fall

its motion; if the direction of this force be oblique to the direction of the moving body, it will give it a new direction.

26. To every action of one body upon another, there is an equal contrary *re-action;* or mutual actions of bodies on each other are equal and in contrary directions, and are always to be estimated in the same right line.

Obs. Whatever quantity of motion any body communicates to another, or whatever degrees of resistance it takes away from it, the acting body receives the same quantity of motion, or loses the same degree of resistance, in the contrary direction: the resistance of the body acted upon producing the same effect upon the acting body, as would have been produced by an active force equal to, and in the direction of, that resistance. Hence it appears, that one body acting upon another, loses as much motion as it communicates; and that the sum of the motions of any two bodies in the same line of direction, cannot be changed by their mutual action.

27. The velocity of motion is estimated by the time employed in moving over a certain space, or by the space passed over in a certain time. The less the time, and the greater the space moved over in that time, the greater is the velocity.

Illus. 1. *To ascertain the degree of velocity,* the space run over must be divided by the time.

2. *To measure the space run over, the velocity must be multiplied by the time;* for it is evident, that if either the velocity or the time be increased, the space run over will likewise be increased.

3. If the velocity be doubled, then the body will move over twice the space in the same time: if the time be twice as great, then the space will be doubled: but if the velocity and time be both doubled, then will the space be four times as great.

Exam. 1. If a ship sail at the rate of 12 miles in an hour, or sixty minutes, then the velocity is equal to one mile in five minutes.

2. If two persons set out together on a journey, and one walks two miles and a half, and the other walks five miles, an hour, the velocity of the latter, will be double that of the former.

28. A body in motion must every instant tend to some particular point. In which case the motion will be in a ght line, or it may be continually changing the point

to which its motion is directed; and this will produce a curvilinear, or circular motion.

29. If a body is acted upon only by one force, or by several forces in the same direction, its motion will be in the same direction in which the moving force acts.

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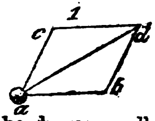

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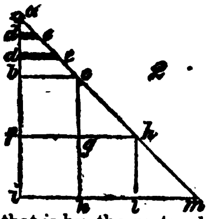

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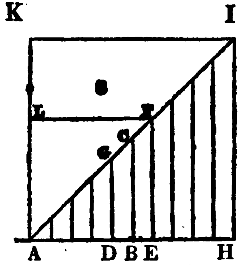

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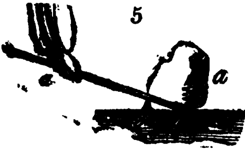
When is motion said to be *retarded*?
Demonstrate the laws of falling bodies by a diagram.
What laws do falling bodies observe in a vacuum?
At what rate are the velocities of falling bodies increased?
What is the rule for estimating the force of a moving body?
Illustrate this rule.

67. There are *three* kinds of levers, distinguished according to the different positions of the *fulcrum* and the moving *power* with respect to each other.

68. In all kinds of continuous levers, the power, is to the resistance, as the distance of the resistance from the fulcrum is to that of the power from the fulcrum.

69. A lever of the *first* kind, is when the fulcrum is placed between the weight and the moving power, as in fig. 5.



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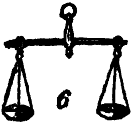
Exam. If it be required to raise the stone *a*, which weighs 1,000 pounds, by the strength of a man equal to 100 pounds weight; a lever *ce*, which rests on the prop *b*, is placed with one end under the stone and the man presses it down at the other end *c*. As the man's strength is only equal to the tenth part of the weight of the stone, the arm of the lever *bc*, must be ten times as long as the arm *be*, in order that the power and weight might balance each other.



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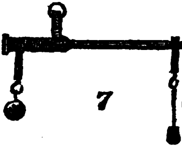

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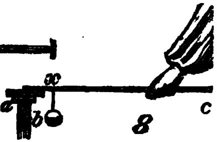

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Illus. 1. A *balance* is a lever of the first kind, with equal arms, see fig. 6.

2. A *steel yard*, fig, 7, is also the first kind of lever with a moveable weight.

3. A *poker*, in the act or stirring the fire, is a lever of this kind: the bar of the grate upon which it rests is the fulcrum; the coals, the weight to be overcome; and the hand is the power.

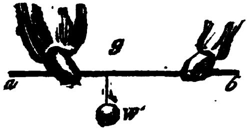
Obs. 1. To this kind of lever, may be referred, *scissors, pincers, snuffers, &c.* which are made of two levers, acting contrary to each other. The fulcrum in these cases, is the pin which keeps them together.

2. The lever of the first kind is chiefly used for loosening large stones; or to raise great weights to small heights, in order to get the ropes under them.

70. The *second kind of lever*, is when the fulcrum is at one end, the power at the other, and the weight between them.

Obs. 1. See fig. 8, where *a* is the fulcrum, *b* the weight, and *c* the power.

2. The advantage gained by this lever is as great, as the distance of the power from the fulcrum exceeds the distance of the weight from it; thus if the hand at *c* be nine times as far from A as the point X on which the weight acts, then the force of one pound at *c*, will balance the weight *b* of nine pounds.

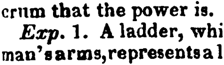


Illus. 1. This kind of lever explains why two men carrying a burthen, as a cask, upon a pole, may bear unequal shares, according to the strength, by placing it nearer to the one than the other; see fig. 9. Here the weight *w*, is twice nearer to *a* than *b*; of course, *a* would bear twice as much weight as *b*.

2. This is applicable to the case of two horses of unequal strength, where the beam may be so divided, that the horses shall draw up in proportion to their respective ability.

3. To this kind of lever may be referred oars, rudders of ships, doors turning on hinges, and cutting knives which are fixed at one end.

71. A lever of the *third kind* is when the prop is at one end, the weight at the other, and the power applied between them. Here the power must exceed the weight in the same proportion, as the distance of the weight from the prop, exceeds the distance of the power.

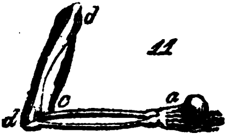


Illus. 1. Let *f* fig. 10, be the prop or fulcrum, *p* the power, and *w* the weight; if the distance *pf* be only three inches, and *wf* be twelve, then for the hand *p* to balance the weight of 20 lbs. will require a force of four times 20, or 80 lbs. because the weight is at four times the distance from the fulcrum that the power is.

Exp. 1. A ladder, which is to be raised by the strength of a man's arms, represents a lever of this kind, where the fulcrum is that end which is fixed against the wall, or upon which another man stands; the weight may be considered as at the top part o the ladder, and the power is the strength applied to the rearing of it

2. The wheels in clock and watch work, may be reckoned levers of this kind, because the power that moves them acts near the *centre* of motion, by a pinion, and the resistance it has to overcome, acts against the teeth at the *circumference*.

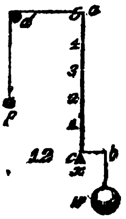
3. The bones of a man's arm, and the greatest number of the moveable bones of animals, are levers of the third kind.



To take the arm, fig. 11, as an instance— *d* the elbow, is the centre of motion, the power, is the motion inserted at *c*, about one tenth part as far below the elbow as the hand is, and *a* is the weight to be raised; the muscles must accordingly exert a power equal to one hundred pounds to raise a weight of ten pounds.

Corol. Hence, in *natural* levers, the power is disadvantageously situated, owing to the power being so near the centre of motion, but the loss of power is compensated by the beauty and compactness of the limb.

69. A *hammer-lever* differs only in its form from a lever of the first kind.



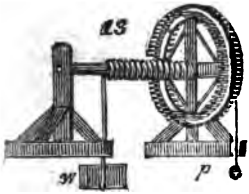
Illus. Let *a c b*, fig. 12, represent a lever of this kind, bended at *c*, which is the fulcrum. *p* is the power acting upon the longer arm *a c*, by means of the cord *a d* going over the pulley *d*; and the weight *w* acts upon the shorter arm *c b*, of the lever. As *a c* is five times as long as *c b*, a weight of five pounds at *p*, will balance 25 pounds at *w*.

Exp. If the shaft of a hammer is six times as long as the iron part that draws the nail, the lower part *c* resting on the board *w* as a fulcrum, then, by pulling at *a*, a man will draw a nail with one-sixth part of the power that he must use to pull it out with a pair of pincers; in the latter case, the nail would move as fast as the hand, but in the former, the hand would move over six times as much space as the nail during the time of drawing it out of the wood.

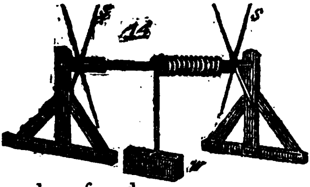
OF THE WHEEL AND AXIS.

73. The *wheel and axis*, though made in many forms, consists of a cylinder, and a wheel fastened to it, (*fig.* 13,) or of a cylinder with projecting spokes, (*fig.* 14.)

74. The advantage gained is in proportion as the circumference of the wheel is greater than that of the axis; or as the diameter of the wheel is greater than the diameter of the axis.



Illus. If the diameter of the wheel, fig. 13, or the length of the spoke, fig. 14, be four feet, and the diameter of the axis only 8 inches, then the power P, of one hundred lbs. or the strength of a man applied to the spokes S, equivalent to a hundred pounds, will balance a weight W of six hundred pounds.



In this case as in the lever, the power will travel over six times as much space as the weight, when the machine is put in motion.

Exam. 1. To this engine, cranes of all kinds for raising heavy weights may be referred.

2. Sometimes the axis is turned by a winch fastened to it, which serves for a wheel, and the power gained is in proportion as the winch is larger than the axis.

3. A capstan is a cylinder of wood, with holes in it; into these, bars are put to turn it round. The bars are made to act something like the spokes, fig. 14.

OF THE PULLEY.

75. The pulley is a small wheel turning on an axis with a rope passing over it. *See fig.* 15.

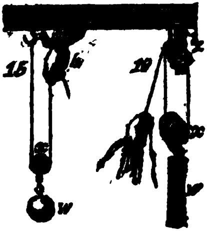
Illus. The small wheel *x* is called a sheeve, and is so fixed to a block *a*, as to be moveable round a pin passing through the centre.

76. Pulleys are either *fixed* or *moveable*.

Obs. 1. The fixed pulley gives no mechanical advantage, but is used only to change the direction of a power. By it a man may raise a weight to any height, without moving from the place in which he is, as a stone to the top of a building, otherwise he must ascend with the weight.

77. The moveable pulley represented by *x*, fig. 16, is fixed to the weight, and rises and falls with it, and the advantage gained by it is as 2 to 1.

1. The reason of this is evident, for in raising the weight one inch, foot, or yard, both sides of the rope must be shortened as much, that is, the hand *h* must move through two inches, feet, or yards; which shews, as before, that the space through which the power moves, must always be in proportion to the advantage gained.



2. When the upper *fixed* block, *z*, fig. 16, contains *two* pulleys, which only turn on their axis, and the lower moveable block *x* contains also two, which turn and rise with the weight W, the advantage gained is as *four* to *one*. For each pulley in the lower block will be acted upon by an equal part of the weight, and since in each pulley that moves with the weight a double increase of power is gained, therefore the advantage gained is as *four* to *one*.

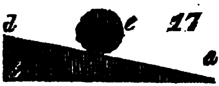
78. In general the advantage gained by pulleys is found by multiplying the number of moveable pulleys by 2.

Obs. 1. A weight W of 72 lbs. may be balanced by four moveable pulleys, by a power of nine pounds, because 72 divided by 8 gives 9; but in this case the power, when put in motion, will pass over 8 times as much space as the weight; that is, to raise the weight one foot, the hand must move over eight feet.

2. A pair of blocks with a rope is called a *tackle*.

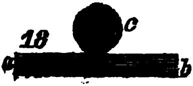
OF THE INCLINED PLANE.

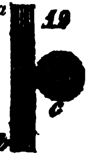
79. The inclined plane is merely a plane surface inclined to the horizon, and is used to move weights from one level to another, *see fig.* 17.



Obs. It is often made by placing boards, or earth, in a sloping direction, and is of great importance in rolling up heavy bodies, as casks, wheel-barrows heavily loaded, &c.

80. The force with which a body descends upon an inclined plane, is to the force with which it would descend perpendicularly, as the height of the plane is to its height.

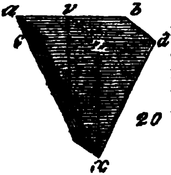




Illus. If the plane *a b*, fig. 18, be parallel to the horizon, the cylinder *c* will rest on any part of it wherever it is laid. But if the plane be placed perpendicularly as *a b*, fig. 19, the cylinder will descend with its whole weight, and would require a power equal to its weight, to keep it from descending. Or, if the plane be inclined to the horizon as *a d*, fig. 17, and *three* times the length of the perpendicular *b d*, the cylinder *e* will be supported by a power equal to a *third* part of its weight. And if the plane be 20 feet long, and the perpendicular height be 4 feet, or *one-fifth*, then 500lbs. would be balanced upon it by 100lbs. because the plane is five times the length of the perpendicular height to which the weight is to be raised. To the inclined plane may be reduced *hatchets*, *chisels*, and other *edge tools*, which are sloped only on one side.

OF THE WEDGE.

81. The WEDGE may be considered as two equally *inclined planes* united at their bases. The advantage gained is in proportion as the length of the two sides of the wedge is greater than the back, or as the length of one side is greater than half the back.



Illus. The wedge *a b c d x*, (see fig 20,) may be divided into two inclined planes, *a v c x*, and *b v d z x*, which may be used separately, and will gain advantage as such; therefore, when united at *z x*, the advantage gained will be in the same proportion, as when they were used in different parts.

Obs. When the wood cleaves at a distance before the wedge, the advantage then gained is in proportion as one side of the cleft is greater than half the length of the back.

82. The wedge is a very important mechanical power, used to split rocks, timber, &c. which could not be effected by any other mechanical power.

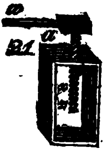
Ob. All instruments, and some sorts of chisels chamfered on both sides, are to be referred to the principle of the wedge.

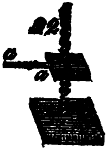
OF THE SCREW.

83. The Screw is an inclined plane used with a lever or winch to assist in turning it; and then it becomes a compound engine of great force, either in pressing bodies closer together, or in raising great weights.

Obs. The screw may be conceived to be made, by cutting a piece of paper into the form of an inclined plane, and then wrapping it round a cylinder; the edge of the paper will form a spiral line round the cylinder, which will answer to the thread of the screw.

84. The advantage gained by this mechanical power, is in proportion as the circumference of the circle made by the lever or winch is greater than the distance between the threads of the screw.





Illus. It is evident that the winch or lever will turn the cylinder once round, whilst the weight, or the resistance, can be moved from one spiral winding to another, as from *x* to *s*, see fig. 21. If the distance of the spirals *s x*, is half an inch, and the lever *a*, three feet, or 36 inches long, then the circle described by the lever will be about 228 inches, or 456 half inches, consequently a force at the end of the lever, equal to only one pound, would balance a resistance at the thread of 456 pounds. Hence it appears, that the longer the winch or lever, and the nearer the spirals, the more advantage is gained. But in the screw there is great loss of power; for a screw may be moved upward or downward in a fixed nut, as in fig. 21, or the nut may move on a screw, as in fig. 22.

85. Almost all kinds of presses, common corkscrews, &c. act upon the principle of this mechanical power.

When a screw turns in a wheel, it is called an *endless* screw.

OF FRICTION.

86. In the application of all the mechanical powers, one-third must be allowed to overcome the FRICTION of the surfaces, and the various other obstacles to which all machines are liable.

Obs. 1. If 60 lbs. are required to balance any weight with a mechanical power, 80 lbs. will be wanted, owing to *friction*, to put the machine in motion.

2. Friction is the resistance a moving body meets with from the surface over which it passes; it is of two kinds, the rubbing by friction, and the friction by contact. The former is represented by a locked waggon wheel going down a hill, the second by the wheel touching the ground in its usual motion. The force of friction varies in proportion to the different surfaces in contact; thus a marble passing on a smooth pavement suffers less from friction than it would from gravel, and it would be impeded in its motion still less if it were driven over ice. But the hardest and most polished bodies are not free from inequalities that retard their motion when they act upon one another. The smallest impediment from friction is, when finely polished iron is made to rub on bell-metal, but even these are said to lose about one-eighth of their moving power. The friction between rolling bodies is much less than in those that drag; hence, in certain kinds of wheel-work, the axle is made to move on small wheels, or rollers, in the inner circumference of the nave. These are denominated friction rollers, and are so placed together in a box, and fastened in the nave, that the axle of the carriage may rest upon them, and they turn round their own centres as the wheel continues its motion. Friction rollers do not answer in very heavy machines, as the pressure is apt to wear the naves into notches; but in light and rapid motions they are extremely useful. Larger metal balls, on the same principle, are made use of in moving immense blocks of stone.

3. After a great variety of experiments made with the utmost care and attention, Mr. VINCE deduces the following conclusions, which may be considered as established facts:

Illus. 1. That friction is an uniformly retarding force in hard bodies, not subject to alteration by the velocity, except when the body is covered with woollen cloth, &c. and in that case the friction increases a little with the velocity.

2. Friction increases in a less ratio than the weight of the body, being different in different bodies. It is not yet sufficiently known for any one body, what proportion the increase of friction bears to the increase of weight.

3. The smallest surface has the least friction; the weight being the same. But the ratio of the friction to the surface is not accurately known.

QUESTIONS ON THE MECHANICAL AFFECTIONS OF MATTER.

What are the *Mechanical powers?*

What are the principal moving powers?

What is the power most easily applied, and whose action most uniform?

What are the three circumstances to be considered in treating of Mechanical contrivances?

What are the six mechanical powers?

How can the force of a small body be made equal to that of a large one?

What is the *lever?*

What is the *fulcrum?*

Where is the *resistance* placed?

On what part of the lever is the *power* applied?

How many kinds of levers are there?

How are they distinguished?

Describe the *first* kind of lever.

What are the uses of this kind of lever?

Draw a diagram, pointing out the *resistance, short arm, long arm, fulcrum, and power.*

Describe the *second* kind of lever.

Where is the fulcrum, power, &c.?

What are the uses of the second kind of lever?

Describe the *third* kind of lever.

Where is the prop?

Where is the weight, and where the power?

Give a natural illustration of this kind of lever.

What is the *hammer lever?*

What are its principles and uses?

Of what does the *wheel and axis* consist?

How is the power gained by the wheel proportioned to the relative diameters of the wheel and axis?

On what mechanical principle does the wheel and axis gain power?

What is the *pulley?*

What is the use of the fixed pulley?

What proportion of advantage is gained by the moveable pulley?

Explain the reason why a weight can be raised more easily with a pulley than without one.

What is the rule for finding the advantage gained by pulleys?

What is a pair of blocks with a rope called?

What is an *inclined plane?*

Of what every day use is the inclined plane?

How is the velocity with which a body descends on an inclined plane estimated?

Explain the diagram.

On what principle does the *wedge* act?

What is the *screw?*

What is the rule by which the force of a screw and lever is estimated?

Explain the principle of the screw.

Illustrate this principle by an explanation of the figure.

In the application of the mechanical powers, what allowance must be made for *friction?*

What is friction?

What are the kinds of friction?

What are the conclusions of Mr. Vince on this subject?

HYDROSTATICS,

OR THE LAWS OF FLUIDS.

87. HYDROSTATICS treat of the nature, gravity, pressure, and motion of fluids in general, and of the methods of weighing solids in them. And its mechanical practice, called hydraulics, relates particularly to the motion of water through pipes, &c.

88. A fluid is a body, the parts of which yield to any impression, and are easily moved among each other. Fluids are either non-elastic and incompressible, as water, oil, mercury, &c. or elastic and compressible, as air, steam, and the different gases.

Obs. Heat, or motion, is supposed to be the cause of fluidity; for example, *ice*, without heat, is a solid—with heat, it becomes a fluid, in *water*—and with more heat, an elastic fluid, in *steam*. In the first state, the atoms are fixed in crystals—in the second, are thrown into intestine motion—and in the third state, are forced asunder with an amazing expansive force.

2. Philosophers have usually assumed, that the particles of fluids are round and smooth, since they are so easily moved among one another. This supposition will account for some circumstances belonging to them. If the particles are round, there must be vacant spaces between them, in the same manner as there are vacuities between cannon balls that are piled together; between these balls smaller shot may be placed, and between these, others still smaller, or gravel, or sand, may be diffused. In a similar manner, a certain quantity of particles of sugar can be taken up in water without increasing the bulk; and when the water has dissolved the sugar, salt may be dissolved in it, and yet the bulk remain the same; and admitting that the particles of water are round, this is easily accounted for.

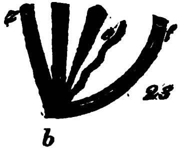
3. Others have supposed, that the cause of fluidity is the mere want of cohesion of the particles of water, oil, &c. and from this imperfect cohesion, fluids in small quantities, and under peculiar circumstances, arrange themselves in a spherical manner, and form drops.

89. Fluids are subject to the same laws of gravity with solids; but their want of cohesion occasions some peculiarities. The parts of a solid are so connected as to form a whole, and their weight is concentrated in a single point, called the centre of gravity: but the atoms of a fluid gravitate independently of each other.

90. Fluids press not only like solids, perpendicularly downwards, but also upwards, sideways, and in every direction.

Exp. Take a glass tube open at both ends, put a cork in one end, and immerse the other in water. The fluid will not rise far in the tube; but the moment the cork is taken out, it will rise to a level with the surrounding water; which proves the pressure upwards.

91. A fluid kept in an open vessel, or vessels, will assume a flat surface parallel to the horizon, and will remain at rest, or rise to a common level.



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Exp. If a vessel, *fig.* 23, consists of pipes variously inclined, communicating with each other at *b*, and open at the top, water poured into any one of them will rise to the same level *z f*, in all.

92. The pressure of the same fluid is in proportion to the perpendicular height, and is exerted in every direction; so that all the parts, at the same depth, press each other with equal force in every direction.

Exp. 1. If a bladder full of air be immersed in water, then the perpendicular pressure is manifest, for the deeper the bladder is immersed, the more will its bulk be contracted.

2. An empty bottle being corked, and by means of a weight, let down a certain depth into the sea, it will be broken, or the cork will be driven into it by the perpendicular pressure.—But a bottle filled with water, wine, &c. may be let down to any depth, without damage, because in this case the internal pressure is equal to the external.

3. It is evident, that the quantities of water in the different pipes, *fig.* 23, whatever be their size, press equally against each other, for if the water be suddenly taken out of the pipes *e*, *z*, or *f*, the surface of the water will instantly descend to a lower level in all the other pipes.

93. The horizontal bottom of a vessel sustains the pressure of a column of the fluid, the base of which is the bottom of the vessel, and the perpendicular height equal to the depth of the fluid.

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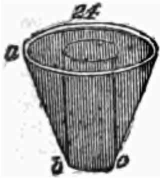

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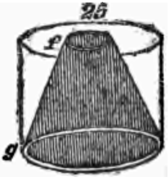

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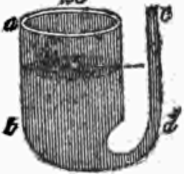


Exp. 1. In the vessel *a b*, *fig.* 24, the bottom *c b* does not sustain a pressure equal to the quantity of the whole fluid, but only of a column, whose base *c b*, and height *b a*.

2. In the vessel *f g*, *fig.* 25, the bottom *g* sustains a pressure equal to what it would be if the vessel was as wide at the top as the bottom.

94. The pressure of a fluid upon any given part of the bottom or sides of a vessel, is equal to the weight of a column of that fluid, having a base equal to that part of the bottom or side, and an altitude equal to the perpendicular height of the fluid.

Obs. 1. Hence may be calculated the pressure upon, and the strength required for dams, cisterns, pipes, &c.

2. The *pressure* of fluids differs from their *gravity* or *weight* in this; the *weight* is according to the *quantity*, but the *pressure* is according to the *perpendicular height*.

3. From this property also, we ascertain the principle of spouting fluids. If a hole is bored in the side of an upright pipe filled with water, the fluid will spout out, which shews the lateral pressure, and this pressure is so much greater, in proportion as the hole is farther removed from the surface; that is, a hole three feet below the surface of a vessel of water will throw out, in the same time, much more water than one only a single foot below.

95. The hydrostatical paradox is this: that any quantity of fluid, however small, may be made to counterpoise any quantity, however large.

Exp. If to the wide vessel *a b*, *fig.* 26, a tube *c d* be attached, and water be poured into either of them, it will stand at the same height in both. Of course, the small quantity in *c d*, balances the large quantity in *a b*. But this is only a paradox in terms, because the action of the fluid is downward, not upward.

96. The upper pressure of fluids is shewn by the hydrostatical bellows.

Exp. 1. This machine consists of two oval boards, 16 inches in length, and about 14 in width, covered with leather, to rise and fall like the common bellows, but without valves. A pipe three feet long is fixed to the top board; let a little water run into the bellows to separate the boards, then weights to the amount of two or three hundred pounds may be put on the upper board; after which, if the pipe be supplied with water, it will, by its upper pressure, sustain and lift up the weights.

2. Upon the principle of the upward pressure, lead or other metal may be made to swim in water. Into a vessel of water

plunge a glass tube, open throughout; but by a string hold a flat piece of lead (1-4 of an inch thick,) fast to the bottom of the tube to prevent the water from getting in between the lead and the glass. In this situation, if the tube is immersed in the vessel of water to about three inches depth, the string may be let go, but the lead will not fall; it will be kept adhering to it by the upward pressure below it. The lead being about eleven times heavier than water, and the three inches being eleven times the thickness of the lead, is the reason why that depth is fixed on. Had iron been used, the depth must have been less than two inches, because iron is 7 or 8 times heavier than water; and if the plate had been of gold, the depth to which it must have been plunged, would have been nearly 5 inches, because gold is 18 or 19 times heavier than water.

97. A fluid specifically lighter than another fluid will float upon its surface. For the lighter fluid will be less powerfully acted upon by the force of gravitation than the heavier; whence, the heavier will take the lower place.

Exp. 1. Let a small and open vessel of wine be placed within a large vessel of water, the wine will ascend.

2. Let mercury, water, wine, oil, spirits of wine, be put into a phial in the order of their specific gravities; they will remain separate.

98. If a body floats on the surface of a fluid specifically heavier than itself, it will sink into the fluid till it has displaced a portion of fluid equal in weight to the whole solid.

Obs. A body, floating on a liquor specifically heavier than itself, will sink into it, till the immersed part takes up the place of so much fluid as is equal to it in weight. For, in that case, that part of the surface of the fluid upon which the body rests, is pressed with the same degree of force, as it would be was the space full of the fluid; that is, all the parts of the surface are pressed alike, and, therefore, the body, after having sunk into the fluid till it is in equilibrio with it, will remain at rest.

Exp. 1. Place a cube of wood in a small jar, exactly filled with water; a part of its bulk will be immersed, and will displace a quantity of the water. Take the cube out of the water, and put it into a scale, with which an empty vessel in the other scale stands balanced. Then pour water into that vessel till the equilibrium is restored, and that portion of water will exactly fill up the jar in which the cube was placed. Consequently, the weight of the water displaced is exactly equal to the weight of the wood.

2. Let a glass jar, with a weight sufficient to make it sink in water to about two-thirds of its length, be placed first in a large vessel of water, and afterwards in one which is very little wider than the jar, and which has in it a small quantity of water; the jar will sink to the same depth in both vessels, that is, till so much of the vessel is under water as is equal in bulk to any quantity of fluid whose weight is equal to that of the whole vessel.

OF SPECIFIC GRAVITY.

99. By the *specific gravities* of bodies, is meant the relative weights which equal bulks of different bodies have in regard to each other.

Obs. 1. Thus a cubic foot of cork is not of equal weight with a cubic foot of water, or marble, or lead; but the water is four times heavier than the cork, the marble 11 times, and the lead 45 times; or, in other words, a cubic foot of lead would weigh as much as 45 of cork, &c. &c.

2. The terms *absolute gravity* and *specific gravity* very frequently occur in physics. The first is what we express in common life by the word *weight*, and signifies the whole of the power, with which a body presses downward to the earth. Every particle in every substance is heavy; that is, it has a tendency to fall toward the earth, or is attracted by the earth. Now, the greater the number of particles a substance has, the more powerful will be its tendency toward the earth; and we express the degree of this tendency by certain quantities, on which we have fixed as standards, by ounces, pounds, &c. Thus we say, rightly, this stone *weighs* sixteen times as much as this ounce. It is very common, however, to say, that stone is as *heavy* again as this; that pound weight is sixteen times as *heavy* as this ounce; but this, in a physical sense, is improper; the two stones, if they be of the same kind, are equally *heavy*, bulk for bulk. Their heaviness or gravity is the same, but their weight is different.

100. It is usual to compare the weight of bodies with that of water, as it is by weighing them in water that their various specific gravities are most conveniently found,

Obs. The method of ascertaining the specific gravities of bodies was discovered accidentally by Archimedes. He had been employed by the king of Syracuse to investigate the metals of a golden crown, which he suspected, had been adulterated by the workmen. The philosopher laboured at the problem in vain, till, going one day into the bath, he perceived that the water rose in the bath in proportion to the bulk of his body; he instantly saw that any other substance of equal size would have raised the water just as much, though one of *equal* weight and of *less* bulk could not have produced the same effect. He immediately felt that the solution of the king's question was within his reach, and he was so transported with joy, that he leaped from the bath, and running naked through the streets, cried out, "Ευρηκα, Ευρηκα,"—"*I have found it out,—I have found it out!*" He then got two masses, one of gold and one of silver, each equal in weight to the crown, and having filled a vessel very accurately with water, he first plunged the silver mass into it, and observed the quantity of water that flowed over; he then did the same with the gold, and found that a less quantity had passed over than before. Hence he inferred that, though of equal weight, the bulk of the silver was greater than that of the gold, and that the quantity of water displaced was, in each experiment equal to the bulk of the metal. He next made a like trial with the crown, and found it displaced more water than the gold, and less than the silver, which led him to conclude, that it was neither pure gold, nor pure silver.

101. A body immersed in a fluid will sink to the bottom, if it be heavier than its bulk of the fluid: and if it be suspended in it, it will lose as much of what it weighed in air, as its bulk of the fluid weighs.

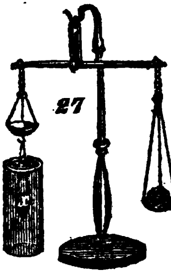
102. All bodies equal in bulk, which would sink in fluids, lose equal weights when suspended therein; and unequal bodies of equal weights lose in proportion to their bulks.

Obs. This is the foundation of the whole doctrine of specific gravities. The fluid is a common and uniform measure of weight, with which the other bodies are compared and contrasted.

103. If the same body be successfully placed in fluids of different specific gravities, it will displace more of the lighter than the heavier fluid; and if the weight of

the body be equal to that of the same bulk of the fluid, then it will remain at rest in any part of that fluid.

104. The HYDROSTATIC BALANCE, used to find the specific gravities of bodies, differs but little from the common balance, (see fig. 27.) It has a hook at the bottom of one of the scales, on which different substances that are to be examined may be hung by horse hairs.



27

Illus. If a body *x* fig. 27, suspended under the scale be first counterpoised in air by weights in the opposite scale, and immersed in water, the equilibrium will be destroyed; then if a weight be put into the scale from which the body hangs to restore the equilibrium, that weight will be equal to the weight of water as large as the immersed body.

Obs. The instrument used for comparing the specific gravites of liquids is called the HYDROMETER; and is used to prove or ascertain the strength of spirits, try the strength of wort, and examine the saturation of brine in salt-works. The deeper the hydrometer sinks in spirits, the better they are; in worts and brine the contrary. Hydrometers are commonly hollow balls of glass, with a smaller ball, containing quicksilver at the bottom, and a slender tube at the top. The tube or stem is graduated, that the depth to which it sinks may be known.

105. The specific gravity of all bodies that sink in water may be found, first by weighing the body in air, then in water, and dividing the weight in air by the loss of weight in the water.

Exam. A guinea weighs 129 grains in air; by being weighed in water it loses 7 1-4 grains, which shews, that a quantity of water of equal bulk with the guinea, weighs 7 1-4 grains; divide 129 by 7 1-4, or 7.25, and the quotient will be 17.793, which proves the guinea to be 17.793 times heavier than its bulk of water.

Corol. 1. We hence easily deduce the methods of obtaining the specific gravities of all bodies, taking rain water as a standard, a cubic foot of which being uniformly found to weigh 1000 avoirdupois ounces.

The weight which a body loses in a fluid, is to its whole weight as the specific gravity of the fluid is to that of the body.

If a guinea weigh in air 129 grains, and in being immersed in water lose 7 1-4 of its weight, the proportion will be 7 1-4; 129 :: 1000 to the specific gravity of a guinea. By this method, the specific gravities of all bodies that sink in water may be found and expressed in a table.

2. Hence, if different bodies be weighed in the same fluid, their specific gravities will be as their whole weights directly, and as the weights lost inversely.

If a body to be examined consist of small fragments, they may be put into a small bucket and weighed; and then if from the weight of the bucket and body in the fluid, we subtract the weight of the bucket in the fluid, there remains the weight of the body in the fluid.

3. If the same body be weighed in different fluids, the specific gravity of the fluids will be as the weights lost.

The loss of weight sustained by a glass ball in water and milk is respectively 803 and 831 grains, therefore the specific gravity of water is to that of milk as 803 : 831, that is, as 1.000 : 1.034. By the same method, the specific gravity of water, is to that of spirits of wine as 1.000 to 857.

SPECIFIC GRAVITIES OF VARIOUS BODIES.

Platina	23.000	Milk	1.034
Fine gold	19.640	Box-wood	1.030
Mercury	14.019	Rain water	1.000
Lead	11.325	Oil	.920
Fine silver	11.091	Ice	.908
Copper	9.000	Brandy	.820
Iron	7.645	Living men	.891
Diamond	3.517	Ash	.800
Marble	2.705	Beech	.700
Glass	3.000	Elm	.600
Flint	2.570	Fir	.550
Chalk	1.793	Cork	.240
Coal	1.250	Common air	.00112
Mahogany	1.063	Hydrogen gas	.000105

Obs. 1. The above table shews the specific weights of the various substances contained in it, and the absolute weight of a cubic foot of each body is ascertained in avoirdupois ounces, by multiplying the number opposite to it by 1000, the weight of a cubic foot of water, thus the weight of a cubic foot of mercury is 14019 ounces avoirdupois, or 876 lbs.

2. If the weight of a body be known in avoirdupois ounces, its weight in Troy ounces will be found in multiplying it into .91 145. And if the weight be given in Troy ounces, it will be found in multiplying it into 1.0971.

3. Mr. Robertson, late librarian to the Royal Society, investigated the specific gravity of living men, in order to know what quantity of wood would be sufficient to keep a man afloat in water, supposing that most men were specifically heavier than river water, but the contrary appeared to be the case from trials which he made upon ten different persons, whose mean specific gravity was, as expressed in the table, 0.891, or about 1-9th less than common water. If, however, as in some cases, they are heavier, and, indeed, as the weight of their heads out of the water would generally sink them, it may be worth while to be able to ascertain the weight of *cork* sufficient to buoy up any man.

If, then, as an example, the absolute weight of a middle sized man be 135 pounds, the weight of two cubic feet of water be 123 lbs. the specific gravity of cork be *one fourth* of that of water, and the weight of the cork required be represented by w; then the x lbs. of cork, when wholly immersed, will displace $4x$ lbs. of water; and the weight of the person and the cork, $135+x$, must of course be equal to that of the water displaced by both $123+4x$, in order that the person may swim as required. Hence we have the following equation: $123+4x, = 135+x$. Consequently, $123+3x = 135$. Therefore $3x=135-123=12$. Whence we find $x=4$. *Four* pounds of cork, therefore, will keep such a person from sinking, so that he may remain with his head completely above water.

HYDRAULICS.

106. The science of Hydraulics teaches how to estimate the velocity and force of fluids in motion. Upon the principle of this science all machines worked by water are constructed, as engines, mills, pumps, fountains, &c.

107. Water can be set in motion only by its own gravity; as when it is allowed to descend from a higher to

a lower level: by an increased pressure of the air, or by removing the pressure of the atmosphere, it will rise above its natural level.

Obs. 1. In the former case it will seek the lowest situation, in the latter, it may be forced almost to any height.

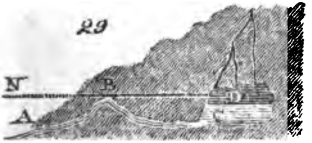
2. Any part of a fluid at rest presses, and is pressed, equally in all directions. For each particle is disposed to give way on the slightest difference of pressure: consequently, it presses equally in all directions. Hence the lateral pressure of a fluid is equal to the perpendicular pressure. *And this is one of the most extraordinary properties of fluids*, and can be conceived to arise only from the extreme facility with which the component particles move among each other.

108. A SYPHON is a bent tube, one of whose legs is longer than the other. The shorter leg is immersed in the liquor to be drawn off, and the pressure of the air being taken from that part of the surface of the liquor within the tube, the liquor will rise above its natural level in the vessel, and will flow off through the longer leg.

28

Obs. 1. A syphon is used by filling it with water or some other fluid, then stopping both ends with the finger, and in this state immersing it in the vessel. The fingers being removed the water flows out of the longer leg, by its own gravity, and afterwards by the pressure of the atmosphere on the liquor in the vessel.

2. Intermitting springs are caused by the principle of the syphon, the water flowing through the natural pipes or syphons from reservoirs of water in the earth, which fill only at certain seasons.



29

Illus. If C be a cavern in a mountain, receiving water which escapes by the channel A B C, it is evident that it will flow only when it rises in D to the level N. B. D.

109. The velocity with which water spouts out at a hole in a side or bottom of a vessel, is in proportion to *the square root* of the distance from the hole below the

surface of the water; and the pressure of water against the sides of a vessel is as the *square* of the depth.

Exam. 1. If at the distance of one foot from the surface, the velocity is 1, another hole four feet from the surface, would give the velocity of 2, and at 9 feet deep there would be a velocity of 3, 2 and 3 being the square root of 4 and 9.

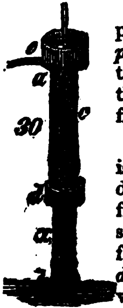
2. If a vessel be three feet deep and filled with water, the pressure upon the sides of the first foot will be 1, on the first and second will be 4, and on the whole side it will be 9.

110. Fluids may be conveyed over hills and valleys in bent pipes, to any height which is not greater than the level of the spring from whence they flow.

Obs. All water finds its own level. But from ignorance of this single principle, the ancients constructed vast aqueducts across valleys to convey water across them; whereas, the moderns effect the same purpose by means of wooden, leaden, iron, or stone pipes.

111. FOUNTAINS are formed upon the same principle: if, near the bottom of any vessel, a small pipe bending upwards be fastened, the water will spout out through the pipe, and rises nearly as high as the surface of the water in the vessel.

112. The COMMON PUMP consists of a pipe open at both ends, in which is worked a moveable piston, that fits the bore exactly, and is provided with *valves*.



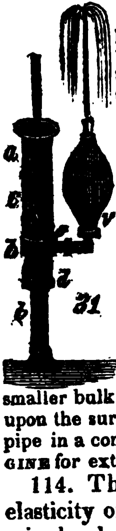
30

Illus. Fig. 30 is the representation of a common pump; *a b* is called the *barrel* which contains the *piston; b d* the pipe communicating with the water below. At the junction of these two parts, there is a fixed *valve* or little trap-door, (see the fig.) *d* opening *upwards*.

The mode of operation is as follows: the part *d* is fixed in water, and the piston *c h* is to be close down upon the valve *d*. In drawing up the piston from *d* to *c*, a vacuum of air is formed in that space, consequently, the air in the rest of the pipe from *d* to *b* will force its way through the valve *d*, and fill the part which had been exhausted; it will therefore, be rarer than before, and not being equivalent to the pressure of the atmosphere upon the water at *d*, in which the pump is immersed, the water will be forced or pressed up into the pipe as far as *x*, until the upper air within be as dense as before.

Upon depressing the piston a second time, the same effect is produced, till at length the water is forced, by the pressure of the air *b*, up into the pipe above *d*. When the piston now descends, it is forced into the water, which, as it cannot repass through the valve *d*, must, therefore, rise above the piston by passing through its *valve c;* and when the piston is next raised, all the water above it will be lifted up, and will run off by the pipe.

113. The Forcing Pump consists of a barrel, a plunger, and two fixed valves, that should be air tight, and so disposed as to let the water freely rise, but prevent its return.



31

Illus. In fig. 31, *a b* is the barrel: *c* a solid piston or plunger; at *d* is one valve opening upwards, the other is the branching pipe *s*. When the piston is first moved upwards in the barrel, the air below will be rarefied and the water rise up in *b*: and by repeated strokes of the pistons, the water will be brought up between the fixed valve *d* and *s*.

It cannot, therefore, descend by *d*, but must make its way through the upper valve at *s*, which shuts the moment the waiter has passed by its own weight.

v is a strong air vessel closed at the top by a small pipe, that reaches nearly to the bottom. The water is forced along the rising pipe *s*, gets into the vessel, and rises above the lower part of the pipe. The air which is above the water in the vessel being confined, and condensed into a smaller bulk than its natural space, presses by its elasticity upon the surface of the water, and forces it violently up the pipe in a continual stream. This is the principle of the Engine for extinguishing fires.

114. The water is raised by pumps owing to the elasticity or pressure of the atmosphere; it can be raised only 33 feet, because the force of the atmosphere is equal only to a column of water 33 feet high.

Obs. 1. The forcing pump is unlimited in regard to the height to which it can throw water. The air-vessel added to the forcing pump, gives the water a more equable stream

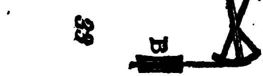
2. A constant stream may be produced by *two* barrels with pistons moving up and down alternately, as is the case in many pumps.

115. The **Steam Engine** consists of a large cylinder or barrel, in which is fitted a solid piston like that of the forcing pump. Steam is thus supplied from a large boiler, which, in forcing up the piston, instantly opens a valve, through which cold water rushes, on the principle of the common pump.

Other steam is then introduced above the piston, which forces it down again, and drives the water out of the pipe with immense force.

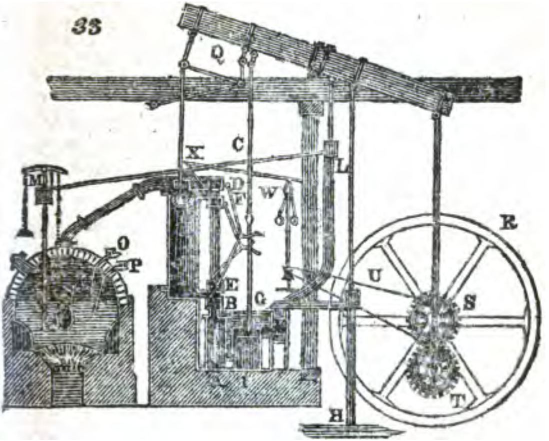
Steam then raises the piston again, and again makes it fall, and by this alternate motion the grandest operations are performed. The action of the piston moves up and down a large beam, and this beam communicates to other machinery, the power of 100 or 200 horses!

Obs. 1. The power of some of the steam engines constructed by Messrs. Boulton and Watt, is thus described, as taken by actual experiment. An engine having a cylinder of 31 inches in diameter, and making 17 double strokes per minute, performs the work of 40 horses, working night and day, for which 3 relays, or 120 horses must be kept, and burns 11,000 pounds of Staffordshire coal per day. A cylinder of 19 inches, making 25 strokes, 4 feet each, per minute, performs the work of 12 horses working constantly, and burns 3700 pounds of coals per day. These engines will raise more than 20,000 cubic feet of water, 24 feet high, for every 100 weight of good pit coal consumed by them.



2. This cut represents the common steam engine. A is the iron cylinder, containing the piston which works up and down, and moves the beam and the resistance B. The steam passes from the boiler, at the pipe D, into the cylinder under the piston, raises it, and the jet at C throws cold water, condenses the steam, and allows the piston to fall again.

33



3. This is Watt's improved engine. The principle is the same as the preceding, but the economy is greater. The steam which is below the piston escapes into the condenser A, by the cock B, which is opened by the rod C, and at the same time the steam is admitted by the cock D into the upper part of the cylinder; when the piston had descended, the cocks E and F act in a similar manner in letting out the steam from above, and admitting it below the piston. The jet is supplied by the water of the cistern G, which is pumped up at H, from a reservoir: it is drawn out, together with the air that is extricated from it, by the air pump I, which throws it into the cistern K, whence the pump L raises it to the cistern M; and it enters the boilers through a valve which opens whenever the float W descends below its proper place. The pipes O and P serve also to ascertain the quantity of water in the boiler. The piston rod is confined to a motion nearly rectilinear by the frame Q. The fly-wheel R is turned by the sun and planet wheel S T, and the strap U turns the centrifugal regulator W, which governs the supply of steam by the valve or stop cock X.

4. Steam engines have been advantageously applied lately to impel vessels in smooth waters, as rivers, canals, &c.

QUESTIONS ON HYDROSTATICS.

Of what do *hydrostatics* treat?

What is the difference between *hydrostatics* and *hydraulics?*

What is a fluid?

What is the cause of fluidity?

Of what shape are the particles of fluids?

In what direction do fluids press?

Illustrate the *upward* pressure of a fluid by an experiment.

What governs the pressure of a fluid upon the bottom of a vessel?

What relation is there between the perpendicular height of a fluid, and its pressure?

Give illustrations of these principles.

How is the pressure of the fluid on the bottom of the vessel calculated?

How does the *pressure* of a fluid differ from its gravity?

What is the *hydrostatical paradox?*

Explain its principle.

Describe the hydrostatical bellows, and explain on what principle it acts.

Explain the manner in which lead may be made to swim upon water.

Explain the reason why a body specifically heavier than water will not sink to any depth in that fluid.

Describe some experiment to illustrate this doctrine.

What is meant by the *specific gravities* of bodies?

What is the difference between *absolute* and *specific* gravity?

Describe the method by which the specific gravity of a body is taken, and explain the principle.

What is the construction of the *hydrostatic balance?*

Explain its use.

Explain the action of the hygrometer.

What is the rule for finding the specific gravity of a body after weighing it in air and in water?

How is the specific gravity of a fluid taken?

What were the results of Mr. Robertson's experiments on the specific gravities of men?

What does the science of *hydraulics* teach?

What useful machines are constituted on the principles of this science?

What are the different ways in which water can be set in motion?

What are the directions in which fluids press?

In what proportion is the lateral to the *perpendicular* pressure of a fluid?

What is a *syphon*?

Illustrate the principles of the syphon.

How are *intermitting* springs caused?

How is the velocity with which water spouts out at a hole in the side of a vessel calculated?

Give an example.

On what principle may water be conveyed over hills in bent pipes?

On what principles are fountains formed?

Describe the *common pump*.

What are the different parts of a forcing pump, and the principles upon which it acts?

How high can water be raised by the common pump, and on what principle?

Describe the steam engine, and give an example of its powers.

PNEUMATICS.

116. The science of Pneumatics treats of the mechanical properties of elastic or aeriform fluids; such as their *weight*, *density*, *compressibility*, and *elasticity*.

117. The air in which we live surrounds the earth, and extends to a considerable height above it. The air, together with the clouds and vapours that float in it, is called the atmosphere.

Obs. 1. This atmosphere is necessary to animal and vegetable life, and to combustion: it is a very heterogeneous mixture, being filled with vapours of all kinds. It consists however of two great principles called *oxygen* in 28 parts, and *azote* in 72 parts, of 100.

2. The height to which the atmosphere extends has never been ascertained; but at a greater height than 45 miles, it ceases to reflect the rays of light from the sun.

118. The air is not visible, because it is perfectly transparent: but it may be felt on moving the hand in it, or when it moves and produces what we call *wind*.

Exp. 1. The existence of the air may be ascertained by swinging the hand edgeways swiftly up and down, which gives the idea of separating the parts of some resisting medium.

2. Any swift motion, as of a stick, or whip, or fan, proves the existence of air as a resisting medium.

119. Air is 900 times lighter than water; but the whole atmosphere presses on all sides like other fluids, upon whatever is immersed in it, and in proportion to the depths.

Exam. 1. It is known that the pressure of the atmosphere is less upon a mountain than in the plain or valley beneath.

2. The pressure of the air may be thus shewn: cover a wine glass completely filled with water, or wine, with a piece of writing paper; then place the palm of the hand over the paper, so as to hold it tight and accurately even. The glass may then be turned upside down, and the hand removed without the water running out. The pressure of the air upon the paper sustains the weight of the water.

3. It is the pressure of the atmosphere which sustains the mercury in the barometer tube. On ascending a mountain the mercury sinks. This shows that a part of the pressure is taken off.

On the surface of the earth the water boils at 212 degrees; on Mount Blanc, it boils at 187 degrees. These and many other experiments shew, the higher we ascend from the surface of the earth, the less is the atmospheric pressure.

120. The air can be compressed into a less space than it naturally occupies.

Exp. 1. Take a glass tube open only at one end, and it is of course full of air. Plunge the open end into a bowl of water, and you see the water rises an inch or so in the tube; the air, therefore, which before filled the whole length of the tube, is compressed by the water into a smaller space.

2. Take a cork swimming on a basin of water, cover it with an empty glass tumbler, which force down through the water. The cork evidently shews, that the surface of the water within the tumbler is not on a level with the surface without. This experiment proves that air is a body which prevents water from occupying the same space with itself; it proves also that the air is compressible, because the water does not ascend in the glass.

121. The air is of an elastic or expanding nature and the force of the spring is equal to what is common-

ly called its weight. The spring, however, operates in all directions, and is as powerful in small as large bulks.

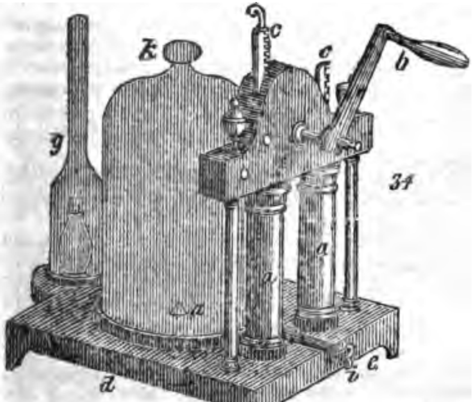
Exp. 1. Fill a bladder with air by blowing into it, and in this state the bladder is highly elastic; it proves also that air is as much a substance as wood or metal, for no force can, without breaking the bladder, bring the sides together, though the parts of an empty bladder may be squeezed into any shape.

2. Open a pair of common bellows in the usual manner, and then stop the nozzle securely, and no force can bring the parts together, without first unstopping the nozzle, or bursting the leather: another proof that air is a solid substance.

122. When air is in motion it constitutes what we call *wind;* which is nothing more than a current of air, varying its force, according to the velocity with which it flows.

123. Air-pumps are machines made for exhausting the air from certain glass vessels adapted to the purpose of experiments on air.

Illus. Fig. 34, represents one of the most convenient air-pumps.



a a two brass barrels each containing a piston, with a valve opening upwards. The pistons are worked by means of the winch *b*, which moves them up and down alternately. On the wooden frame *d e*, there is a brass plate *g*, ground perfectly flat and even; and also a brass tube, communicating with the two cylinders beneath, and the cock *i*, and opening into the centre of the brass plate at *a*.

k is the glass receiver which is to be exhausted of air, and is made to fit very accurately on the brass plate, particularly when a wet piece of leather is laid between them.

Having shut the cock *i*, the pistons are worked up and down, and the air is drawn from the glass receiver through the pipe, and is suffered to escape; when the piston is forced down, the air rises through it, because the valve opens upwards, but it is prevented from returning into the vesssel for the same reason. The air being gradually exhausted from the receiver, it becomes immoveably fixed by the pressure of the surrounding atmosphere.

Upon opening the cock *i*, the air rushes again violently, and with a noise into the receiver.

124. The Air-pump is the grand machine by which experiments on air are made. By its means the following important properties of air are demonstrated.

1. *The air has weight.*

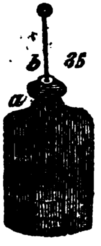
Exp. 1. The air being exhausted by an air-pump, from a glass receiver, the receiver will be held fast by the pressure of the external air.

2. If a small receiver be placed under a larger, and both be exhausted, the larger will be held fast, while the smaller will be easily moved.

3. If the hand be placed upon a small open vessel, in such a manner as to close its upper orifice, it will be held down with great force.

4. The upper orifice of an open receiver being closely covered with a piece of bladder, upon exhausting the receiver, the bladder will be pressed till it burst.

5. Let the air be exhausted from a glass vessel, and by means of a cock, let the vessel be kept exhausted; weigh the vessel whilst it is exhausted, and when the air is to be re-admitted, the difference is the weight of so much air as the vessel contains; which difference will be about 324 grains for a thousand cubic inches.



Into the receiver *a*, fig. 35, put a small vessel of quicksilver, and through the collar of leather as at *b*, suspend a glass tube, closed at the upper end, over the quicksilver. The apparatus thus situated is to be placed on the brass plate of the air-pump, and the air completely exhausted from the receiver, the tube is then to be let down into the quicksilver, which will not rise in it as long as the receiver continues empty; but as soon as the air is re-admitted, all the surface of the quicksilver is pressed upon by the air, except that portion which lies above the orifice of the tube; it will therefore *rise in the tube*, until the weight of the elevated quicksilver presses as forcibly on that part of it which lies beneath the tube, as the weight of the air does on every other equal portion without the tube.

7. A common experiment among boys is on the same principle. Take a piece of thick spongy soal leather, cut it into a circular form, and through the centre pass a string; wet it thoroughly, and place it flat on a smooth surface; then try to pull it up in a perpendicular line. A vacuum is formed in the centre, while the edges are pressed down by the weight of the atmosphere. In this way, a smooth stone of many pounds weight may be lifted.

Obs. 1. Hence the pressure of the atmosphere on or near the surface of the earth is known; the weight of any column of air being equal to the weight of the column of mercury, of the same diameter, supported in the barometer. And, since the height of this column varies with the weight of the atmosphere, (between 28 and 31 inches, equal to 23 feet of water,) the varieties in the weight of the atmosphere are known by the BAROMETER. The most usual altitude of the barometer, in London, is between 28 and 31 inches, but it is seldom seen below 28 1-2 or 30 1-2 inches.

2. In calm weather, when it is inclined to rain, the mercury is commonly low. In serene settled weather, the mercury is generally high. During very great winds, though unaccompanied with rain, the mercury sinks lowest of all.

2. *The air presses equally in all directions.*

Exp. 1. If a glass vessel be filled with water, and covered with a loose piece of paper, on inverting the glass, the water will be kept from falling by the upward pressure of the air.

2. If a vessel be perforated in small holes at the bottom, but closed at the top, the upward pressure of the air will keep the

water within the vessel; as will appear by successively stopping and unstopping a small hole in the top of the vessel, or in drawing beer from an air-tight cask.

3. Two brass hemispherical cups put close together, when the air between them is exhausted, will be pressed together with considerable force.

4. A syringe being fastened to a plate of lead, and the piston of the syringe being drawn upwards with one hand, whilst the lead is held in the other, the air, by its upward pressure, will drive back the syringe upon the piston; whereas, if the loaded syringe be hung in a receiver, and the air being exhausted, the syringe and lead will descend; but upon re-admitting the air, they will again be driven upwards.

5. If a thin glass vessel, whose aperture is closed, be placed under the receiver of an air-pump, and the air exhausted from the receiver, the vessel will be broken by the pressure of air within.

3. The air is an elastic fluid, or capable of compression or expansion.

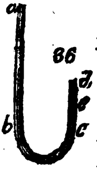
Exp. 1. A blown bladder, pressed with the hand, will return into the form which it had before the pressure.

2. An empty bladder put under a receiver, when the external air is exhausted, becomes extended by the elasticity of the internal air.

3. A bladder suspended within the receiver, with a small weight hanging from it, which touches the bottom, when the external air is exhausted, by the expansion of the internal air, will raise the weight.

4. The bladder being put into a box, and a weight laid upon the lid, the lid, on exhausting the air, will be lifted up.

5. If a tube, closed at one end, be inserted at its open end, in a vessel of water, the fluid in the tube will not rise to the level of the water in the vessel, being resisted by the elastic force of the air within the tube. On this principle the diving bell is formed.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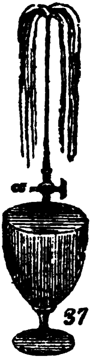
6. This bent tube *a b c d*, fig. 36, is open at both ends. I have poured mercury into the tube so as to rise in both sides of the tube *c* and *b*; the part from *c d*, is full of air at the common density; I stop up *d*, so as to make it air tight, and pour mercury into *a*, so that the column of mercury *a b* shall be equal in length to the height at which it stands in the barometer at the time. The air in the shorter leg will now be compressed by the weight of the atmosere, and also with an additional weight of a column of

mercury; and the mercury in the shorter leg will be risen to *e*, and *a e* is the only half of *d c*; that is, the pressure of a double atmosphere compresses the air to half the space which it naturally occupies. If another equal column of mercury were added to the length *a b*, the air in *d c* would be reduced into one fourth the space that it formerly occupied.



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7. *a* fig. 37, is a strong copper vessel, having a tube that screws into the neck of it, so as to be air-tight, and long enough as nearly to reach the bottom; *x* is the handle of a stop-cock. Having poured some water into the vessel, and screwed in the tube, the condensing syringe is to be adapted, and the air condensed. The stop-cock is to be shut, while the syringe is unscrewed, then, on opening the cock, the air, by its great density acting upon the water in the vessel, will force it out in a jet to a considerable height. This is called the artificial fountain.

4. *The elastic spring of the air is equivalent to the force which compresses it.*

Exp. Let the air be exhausted from an open tube, whose lower part is inserted in a vessel containing a small quantity of mercury, and let the air within the vessel be prevented from escaping; this air, by its elasticity, will force the mercury up the tube nearly to the height to which it would be raised by the pressure of the atmosphere.

Obs. If the spring with which the air endeavours to expand itself when it is compressed, were less than the compressing force, it would yield still farther to that force; if it were greater, it would not have yielded so far. Therefore, when any force has compressed the air so that it remains at rest, the spring of the air rising from its elasticity must be equal to the pressure.

5. *The elasticity of the air is increased by heat.*

xp. 1. To the bottom of a hollow glass ball, let an open bended tube be affixed. Let the lower part of the bended tube and part of the ball be filled with mercury; the external surface will be pressed by the weight of the atmosphere; and the internal surface will be equally pressed by the spring of the air enclosed within the vessel. If the ball be immersed in boiling water, the increased elasticity of the included air will raise the mercury in the small tube. The same may be shewn by immersing in boiling water, a tube, closed at one end, into which a small quantity of mercury has been admitted, inclosing a portion of air within the tube.

2. The wind is no other than the motion of the air upon the surface of the globe. The principal cause of wind, is, that the atmosphere becomes heated over one part of the earth more than over another. For, in this case, the warmer air being rarefied, becomes specifically lighter than the rest; it is therefore overpoised by it, and raised upwards, the upper parts of it diffusing themselves every way over the top of the atmosphere; while the neighbouring inferior air, rushes in from all parts at the bottom; which it continues to do until the equilibrium is restored. Upon this principle it is, that most winds may be accounted for.

3. Fill a large dish with cold water; into the middle of this put a water-plate, filled with warm water. The first will represent the ocean; and the other an island, rarefying the air above it. Blow out a wax candle, and if the air be still, on applying it successively to every side of the dish, the smoke will be seen to move towards the plate. Again, if the ambient water be warmed, and the plate filled with cold water, let the smoking wick of the candle be held over the plate, and the contrary will happen.

6. *The pressure of the atmosphere varies at different altitudes.*

Exp. Put a glass tube, open at both ends, through a cork, into a large phial containing a small quantity of coloured water; let the lower end of the tube be in the water, and let the cork and tube be closely cemented to the neck of the bottle. Then blow through the tube, till the quantity of the air within the phial is so increased, that the water will rise above the neck of the phial. Let this phial be placed in a vessel of sand, to keep the air within of the same temperature; the water will stand at different heights in the tube, according to the elevation of the place where it is placed; from whence is appears, that the pressure of the atmosphere varies at different altitudes.

Corol. Hence the proportion of the specific gravity of air to that of water may be determined. If the difference in height of the two places where the above experiment is made be 54 feet, and that difference cause a difference of

3-4 of an inch in the height of the water; it follows, that a column of water of 3-4 of an inch, or 1-16th of a foot, is equiponderant to a column of air of 54 feet, having the same base; therefore, the gravity of air to that of water, is 54 to 1-16th, or 864 to 1. In ascending the mountain of Snowden, in Wales, which is 3720 feet perpendicular height, it was found, that the barometer sunk 3 inches and 8-10ths.

PNEUMATIC INSTRUMENTS.

125. The SYRINGE is a hollow tube with a small orifice at one end: at the other end is inserted a solid cylinder, so exactly fitted to the tube that no air can pass along its sides, and a fixed handle to the solid cylinder. If that end of this instrument which has the smaller orifice, be drawn back, a vacuum will be produced within the syringe; and the pressure of the atmosphere on the surface of the water, meeting with no opposite pressure, will force the water into the tube, from whence it may be forcibly expelled by pushing down the piston.

126. The CONDENSER is used to force air into any vessel; it is a syringe, having a solid piston, and a valve in the lower part of its barrel which opens downwards. By thrusting down the piston the air is forced through the valve, which is afterwards held close by the elasticity of the condensed air. When the piston is lifted up, a vacuum is produced, till it is raised above a small hole in the barrel, when the air rushes in, and is again discharged through the valve.

127. The AIR-GUN, is an instrument, in the form of a gun, by which a quantity of condensed air is suddenly set free, and drives a ball through the barrel with great force.

128. The BAROMETER is a very useful instrument for determining the variations of the weather.

Exp. 1. If a glass tube of about 32 or 33 inches long, hermetically sealed at one end, be filled with mercury, and then inverted into a basin of the same fluid, the mercury in the tube will stand at an altitude above the surface of that in the ba between 28 and 31 inches. A tube thus filled, and graduated from 28 to 31 inches, is called a barometer. Hence, as a cubic inch of water weighs 253.18 grains Troy, a cubic inch of air weighs 0.286 grains, and if mercury be 14 times heavier than water, the specific gravity of air is to that of mercury 1 o 886X14=12390.

2. Now the mercury in the barometer tube will subside, till the column be equivalent to the weight of the external air upon the surface of the mercury in the basin, and is therefore a true criterion to measure that weight, and chiefly directed to that purpose, in order to foretel the changes in the weather.

Obs. 1. If each inch in the scale of variation be divided into ten equal parts, marked 1, 2, 3, increasing upwards, and a *vernier* whose length is 1 1-10th of an inch, be likewise divided into ten equal parts, increasing downwards, and so placed as to slide along the graduated scale of the barometer, the altitude of the mercury in the tube, above the surface of that in the basin, may be found, in inches and hundredth parts of an inch, by this *vernier*. If the surface of the mercury in the tube does not exactly coincide with a division in the scale of variation, place the index of the *vernier* even with this surface, and observing where a division of the *vernier* exactly coincides with one of the scale, the figure in the *vernier* will shew what hundredth parts of an inch are to be added to the tenth immediately below the index.

2. If the atmosphere were homogeneous, its altitude would be easily found. For when the mercury stood at 29 1-2 inches, the density of the air being to that of mercury as 1 to 12390; consequently, the altitude of an homogeneous atmosphere would be equal to 12390X29 1-2=5.77 miles.

3. The barometer has been applied to the measuring of *the heights of towers, mountains*, &c. Since 12390 inches of air, near the surface of the earth, are equal to one inch of mercury, 1239 inches, or about 103 feet of air, must be equal to 1-10th of an inch of mercury. Therefore, if a barometer be carried up any great eminence, the mercury will descend 1-10th of an inch for every 103 feet that the barometer ascends.

129. The THERMOMETER is an instrument calculated for measuring the temperature of the air, and bodies, and is usually a cylindrical glass tube, containing spirits of wine, mercury, &c. which fluids are found to swell and occupy different portions of the tube in different temperatures.

Obs. The bulb, and part of the tube is filled with quicksilver; this contracts and expands as the instrument is exposed to more or less heat, and consequently the temperature of contiguous bodies is shown by its rise and fall in the tube, which is measured by a scale.

2. The Thermometer chiefly used in Great Britain, is that constructed by Fahrenheit; in which there are 180 divisions between the freezing point being reckoned 32° above zero, or the commencement of the scale; consequently the boiling water point is 212°

3. The scale on Reaumur's thermometer, which is principally used on the Continent, begins at the freezing point, and proceeds both ways, from 0 to zero. From freezing to boiling water are 80 degrees.

4. Since the thermometers of Fahrenheit and Reaumur are those mostly in use, it will be often found convenient to be able readily to convert the degrees on Fahrenheit's scale into those of Reaumur, and vice versa: and as one degree on Reaumur's scale is equal to 2.25°, or to 90·4th of Fahrenheit; and as the former scale places the freezing point at zero, and the latter places it as 32; the following canons will reduce the degrees on the one to the corresponding one on the other.

Obs. To convert the degrees of Fahrenheit into those of Reaumur; $\frac{\overline{F-32 \times 4}}{9} = R$: thus the 167° of Fahrenheit answers to the 60° of Reaumur.

To convert the degrees of Reaumur to those of Fahrenheit: $\frac{R \times 9}{4} + 32 = F$.

Thus the 40° of Reaumur answers to the 122° of Fahrenheit.

5. Mr. Wedgewood contrived a thermometer for measuring higher degrees of heat, by means of a property of argillaceous bodies, viz. the diminution of their bulk by fire. This diminution commences in a dull red heat, and proceeds regularly as the heat increases, till the clay becomes vitrified.

Each degree of Wedgewood's thermometer answers to 130 degrees of Fahrenheit; and he begins his scale from 1077° Fahrenheit.

	Degrees of Fahrenheit.	*Degrees of Wedgewood.*
Cast iron melts	21877	160
Fine gold melts	5237	32
Fine silver melts	4717	28
MERCURY BOILS	600	
Cow's milk boils	213	
WATER BOILS	212	
Heat of the human body	92 to 99	
WATER FREEZES and snow melts	32	
Milk freezes	30	
Strong wine freezes	20	
MERCURY FREEZES	—39 or 40.	

130. The HYGROMETER is an instrument for measuring the degrees of moisture in the air; of which there are various kinds; for whatever contracts and expands by the moisture and dryness of the atmosphere, is capable of being formed into a hygrometer. Such are most kinds of wood; catgut, twisted cord; the beard of wild oats; the weather house, &c.

QUESTIONS ON PNEUMATICS.

What is the object of the science of pneumatics?

What is the *atmosphere?*

To what height does the atmosphere extend?

How may the existence of the air be ascertained?

How much lighter is air than water?

How is the pressure of the air shown?

How is it known that the pressure of the atmosphere decreases upwards?

What is said concerning the elasticity, or expanding nature of air?

How is this illustrated?

What is *wind?*

What is an *air-pump?*

How is it demonstrated that the air has weight?

What is said concerning the variation of the mercury in the *barometer* tube?

What experiments show that the air presses equally in all directions?

How is it proved that the air is elastic? mention the experiments.

What is said of the force of the elastic spring of air?

What experiments demonstrate that the elasticity of air is increased by heat?

What simple experiment proves that the pressure of the atmosphere varies at different altitudes?

What is a *syringe?*

Describe its action.

Describe the *condenser.*

How is the air-gun constructed?

What is the use of the *barometer?*

How is it constructed?

What is the rule for measuring altitudes with the barometer?

What is the *thermometer?*

On what principle does it show the temperature of air, and of other bodies?

What thermometers are chiefly used in England and in this country?

How is it graduated?

What are the freezing and boiling points?

What is the hygrometer?

Of what substance may it be constructed?

ACOUSTICS.

131. ACOUSTICS is the science which treats of the nature, phenomena, and laws, of the sense of sound. It extends to the theory of musical concord and harmony, and is therefore, a valuable and interesting science.

132. Sound is considered as arising from vibrations in the air, communicated to it by vibrations of the sounding body, acting in pulsations or concentric waves, like the surface of water when a stone is thrown into it.

Obs. If when a piece of artillery is fired at a distance, some dust floating in the air, or a cobweb be closely inspected, it will be seen to be agitated at the instant when the report is heard. This proves that the vibrations of the air travel with the same velocity that sound does, and that it is by means of these vibrations striking on the ear-drum that sounds are conveyed.

133. A sonorous body, whilst sounding, is unquestionably in a state of vibration, and the air, by similar

vibrations, communicates and propagates these vibrations.

134. The chief causes of the variety of sounds, are,
First, the greater or less frequency of the vibration.
Secondly, the quantity or force of the vibrating materials.
And, *Thirdly*, the greater or less simplicity of the sounds.
Hence arise the height, the strength, and the modification of sounds.

Obs. When sounds are equally acute, they are said to have the same pitch; but when they differ in acuteness, that sound which is shriller is said to be acute, or to have a higher pitch; and that which is less shrill, is said to be graver, or to have a lower pitch, or a deeper tone. A difference in pitch, forms the chief character by which musical sounds are distinguished from each other, and is the foundation of their use in music.

135. The vibrations of a sounding body, continue for a longer or shorter time, according as the body is more or less elastic, or as it is thicker or thinner.

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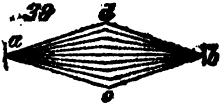

Exam.1. When a string of uniform shape and quality is stretched between, and fixed to, two steady pins, as *a b*, fig. 38, if it be drawn out of its natural or quiescent position *a b*, into the situation *a c b*, and then be let go, it will in consequence of its elasticity, not only come back to its position *a b*, but it will go beyond it, to the situation *a d b*, or nearly as far from *a b*, as *a c b* was on the other side. All the motion one way, is called one vibration: after this, the string will go again nearly as far as *c*, making a second vibration; then nearly as far as *d*, making a third vibration, and so on; diminishing the extent of its vibrations gradually, until it settles again in its original position *a b*.

Obs. 1. During the whole of these vibrations, the string will forcibly act on the air and produce corresponding vibrations in it, which, reaching and entering the ear, produce on the nerves therein, the sense of sound.

2. The following experiment indicates a curious accordance of vibration, and proves that the air re-acts in the exact law of the original vibration.

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Exp. If you divide a string as *a b*, fig. 39, into three equal parts, *ab*, *bc*, *cd*, by placing dots at *c* and *b*; place a bridge like a violin bridge, at *b*, also place light bodies, such as small bits of paper.

at *c*, and other places of the part *b d*. Then draw a violin bow over the part *a b;* you will find that all the bits of paper will be thrown off from the part *b d*, excepting the one at *c;* shewing that the point *c* remains at rest, whilst the remainder of the string is vibrating, just as though *c* also had a stop, as at *b*.

136. Sounds in general are conveyed to the ear by means of the air: but water is also a good conductor of sound; as are timber and flannel.

Exp. 1. A bell rung under water returns a tone as distinct as if rung in air.

2. If you stop one ear with a finger, and the other by pressing it close to a long stick or piece of deal board, and a watch be held at the other end of the wood, the ticking will be heard, be the stick or board ever so long.

3. If you tie a poker or any piece of metal on the middle of a strap of flannel, about two or three feet long, and then press with the thumbs or fingers the ends of the flannel in your ears, while you swing the poker against an iron or steel fender, you will hear a sound like that of a very heavy church bell.

4. If two persons stop their ears, they may converse with each other, by holding the two ends of a stick between their teeth, or, only resting the ends of the stick against their teeth. The same may be done by a series of sticks, with the ends touching each other. The same effect is also produced if the end of the stick rest on the throat, or breast, or if one end of it touch a vessel into which the other speaks. In the last instance the sound is most distinct if the vessel is capable of a tremulous motion, as one of glass, bell metal, or copper.

Sound may also be conveyed from one person to another by a string stretched between their teeth.

137. Sound travels at the rate of 1142 feet in a second, or about 13 miles in a minute. This is the case with all kinds of sounds: the softest whisper flies as fast as the loudest thunder.

Obs. The velocity of sound has been applied to the measurement of distances.

1. A ship at sea in distress fires a gun, the light of which is seen on shore 20 seconds before the report is heard, therefore it is known to be at the distance of 20 times 1142 feet, or little more than 4 1-3 miles.

2. I see a vivid flash of lightning, and if in three seconds I hear a tremendous clap of thunder, I instantly know that the

thunder cloud is only two-thirds of a mile distant, I should therefore retire instantly from any exposed situation.

3. The pulse of a healthy person beats about 76 times in a minute; if, therefore, between the flash of lightning and the thunder I can feel 1, 2, 3, 4, &c. beats of my pulse, I know the cloud is 900, 1800, 2700, 36,000 feet from me.

138. Sound, like light, after it has been reflected from several places, may be collected into one point as a focus, where it will be more audible than in any other part; and on this principle WHISPERING GALLERIES are constructed.

Obs. In the reflection of sound as well as of light, the angle of reflection is equal to the angle of incidence. By the same law therefore, sound may be collected into a focus.

Exp. 1. If the pulses of air conveying sound be suffered to impinge on a concave surface, the reflected vibrations are converged into a focus.

2. The same effect is produced whenever a number of plain surfaces are so situated that the reflected sounds meet, and cross each other at a certain point. If the ear be placed at this point, the sound will be audible in proportion to the number of surfaces so placed. The famous whispering gallery at St. Paul's is on this principle.

139. SPEAKING TRUMPETS, and those made to assist the hearing of deaf persons, depend on the reflection of sound from the sides of the trumpet, and also by its being confined and prevented from spreading in every direction.

Obs. 1. A speaking trumpet, to have its full effect, must be directed in a line towards the hearer; the report of a gun or cannon is much louder when fired towards a person, than one placed in a contrary direction.

2. The human voice is produced by the expulsion of air from the lungs, and by the vibrations excited in that air, by a very small membrane called the *glottis*, in its passage through the trachea or windpipe; and by the subtle modification of the mouth, tongue, and lips.

3. Singing is performed by a very delicate enlargement or contraction of the glottis, aided likewise by the mouth and tongue for articulation.

4. In stringed instruments the air is struck by the string, and the vibrations of the air produce corresponding sounds in the

ear; but in pipes the air is forced against the sides by the breath, and its vibrations or tones produced by the re-action of the sides.

140. An ECHO is the reflection of sound striking against a surface fitted for the purpose, as the side of a house, a brick wall, hill, &c. and returning back again to the ear, at distinct intervals of time.

Obs. 1. If a person stand about 65 or 70 feet from such a surface, and perpendicularly to it, and speak, the sound will strike against the wall and be reflected back, so that he will hear it as it goes to the wall, and again on its return.

2. If a bell situated in the same way be struck, and an observer stand between the bell and the reflecting surface, he will hear the sound going to the wall, and again on its return.

3. If the sound strike the wall obliquely, it will go off obliquely, so that a person who stands in a direct line between the bell and the wall, will not hear the echo.

141. Concord is any succession of sounds that excite in the ear certain agreeable sensations. Sound is therefore the subject matter of musical science. Harmony is the coincidence of two or more sounds, which by their union afford to the mind pleasure and delight.

Obs 1. Concord arises from the agreement of the vibrations of two sonorous bodies; so that some of the vibrations of each strike upon the ear at the same instant.

Thus if the vibrations of two strings are performed in equal times, the same tone is produced by both, and they are said to be in *unison*. If the vibrations strike the ear at different times, there is no unison, and consequently a *discord* is produced.

Obs. 2. Concord is not confined to unison. In this case no variety of tones would be produced. It is the effect of *agreement* between vibrations.

Illus. If the vibrations of one string are double those of another in the same time, the second vibration of the latter will strike upon the ear at the same instant with the first vibration of the former: this makes the concord of an octave.

142. Two strings of equal length, tension and thickness, by performing their vibrations together, will sound the same note, or be in unison. Two pipes of the same length and diameter will agree in the same manner. Large instruments & long strings produce grave or deep

tones: small instruments and short strings produce acute and high tones.

Obs. In the case of the strings, the air is struck by the body, and the sound is excited by the vibrations: in that of the pipes the body is struck by the air, but as action and reaction are equal, the effect is the same.

2. Let a musical string of any length be divided into two equal parts by a bridge in the middle; and the sound of each half is eight notes, or an octave, higher than the tone of the whole string.

Organ pipes produce grave or acute tones in proportion to their length and size. It is the shortest string of a harpsichord which yields the highest notes.

143. Sounds may be conveyed to a much greater distance through a continuous tube, than through the open air.

Illus. Pipes are used in taverns, running from one room to another to convey orders to the servants.

Dr. Herschel employs a similar tube attached to his forty feet telescope for communicating his observations to an assistant who sits in a small house near the instrument; and thus under cover notes them down the particular time at which they were made,

Obs. The tubes used to convey sounds are called *acoustic* tubes.

It is by means of such tubes that the deception of what is called the *invisible lady* is carried on. In this exhibition a square railing of wood is fixed in the middle of the room, and within the railing a globe is fixed, having four trumpets inserted into it,one opposite to each side of the railing. The spectators ask a question by speaking into one of the trumpets, and then on holding the ear to the same trumpet, they receive the answer, This deception is performed by conveying the sound by tubes which are carried from one room to another under the flooring, and within the bar of the railing to a small aperture opposite to the mouth of the trumpet. When the question is asked it is conveyed by this pipe to a person placed in the next room, and the reply is conveyed back to the trumpet by the same tube.

QUESTIONS ON ACOUSTICS.

Of what does the science of *acoustics* treat?
How does sound arise, and how is it communicated?
How is this proved?

What are the principal causes of the varieties of sounds?

What is said about the *pitch* of a sound?

On what does the continuance of vibrations depend, for a longer or shorter time?

What other substances besides air conduct sound?

Give illustrations of the power of liquids and solids to conduct sounds.

At what rate does sound travel through the air?

What is said about measuring distances by the velocity of sound?

On what principle are *whispering galleries* constructed?

What is said of plain and concave surfaces in converging sound into a focus?

On what principle are *speaking trumpets* constructed?

How is the human voice produced?

What parts are concerned in the modulation of the voice in singing?

How does the production of sound by pipes differ from that by strings?

What is an Echo?

How is this accounted for?

What is said concerning the reflection of light and sound following the same laws?

What is *concord?*

From what does concord arise?

When will two strings, or two pipes be in unison?

How may sounds be conveyed to a greater distance than through the open air?

What is said of Dr. Herschel; the *invisible lady*, &c.?

OF OPTICS;

OR

THE LAWS OF LIGHT AND VISION.

144. Light consists, either of small particles emanating from a luminous body, or of vibrations excited by combustion in an universal medium, which, proceeding to the eye, produce the perception of *vision*.

Obs. 1. It is evident we cannot see any object by willing or wishing to see it; but that something must pass from the object to the eye, because no effect can take place without a proximate cause.

2. Sir Isaac Newton supposed rays of light to consist of exceedingly small particles, infinitely smaller than sand, moving from luminous bodies; but the moderns suppose them to consist of the undulations of an elastic medium, which fills all space, and which produces the sensation of light to the eye, just as the vibrations of air produce the sensation of sound to the ear. We shall not prefer either hypothesis in these pages, because either of them will account equally for all the phenomena of light.

145. A *Ray, or pencil of Light*, is any exceedingly small portion of light which comes from a luminous body. A *Beam* of light, is a body of parallel rays; a *Pencil* of rays, is a body of diverging or converging rays.

146. Any body which is transparent, or which affords a ready passage for light, is called a transparent *Medium*, as air, glass, water, &c. Bodies which do not allow the passage of light through them, are called *Opaque*, as stone, wood, &c.

147. Rays of light which coming from a point, continually separating as they proceed, are called *Diverging Rays.* Rays which tend to a common point are called *Converging Rays.* When the lines in which they move are parallel, they are called parallel rays.

148. The point from which diverging rays proceed, is called the *radiant point;* that to which converging rays are directed is called the *focus.* A ray of light, bent from a straight course in the same medium, is said to be *inflected;* when turned back on the surface of a body, it is said to be *reflected;* and, when turned out of its course in passing out of one medium into another, it is said to be *refracted.*

149. Every visible body emits particles of light, or reflects vibrations from its surface in all directions, which, passing without any obstruction, move within the same medium in right lines.

Obs. Wherever a spectator is placed in respect to the luminous body, every point of that part of the surface, which is ed towards him is visible to him; the particles of vibrations of light are, therefore, emitted in all directions, and those rays only are intercepted in their passage by an interposed object, which would be intercepted upon the supposition that the rays move in right lines.

Exp. 1. Let a portion of a beam of light be intercepted by any body; the shadow of that body will be bounded by right lines passing from the luminous body, and meeting the lines which terminate the opaque body.

2. A ray of light, passing through a small orifice into a dark room, proceeds in a straight line.

3. Rays will not pass through a bended tube.

4. Rays of light may, therefore, be properly represented by right lines.

150. Rays or vibrations of light move with great velocity; for the flash of a gun, fired at a considerable distance, is seen some time before the report is heard. The clap of thunder is not heard till some time after the lightning has been seen.

Obs. This proposition is proved by observation made on the satellites of the planet Jupiter, and on the aberration of the rays of light from the fixed stars, from whence it will be seen, that the velocity is at the rate of 200,000 miles in one second of time.

151. The particles of light must be exceedingly small, if they are particles; or the force of the vibrations must be very delicate; otherwise their velocity would render their momentum too great to be endured by the eye without pain.

Exp. 1. If a candle be lighted, and there be no obstacle to obstruct the progress of its rays, it will fill all the space within two miles every way before it has lost the least sensible part of its substance.

2. Rays of light will pass without confusion through a small puncture in a piece of paper, from several candles in a line parallel to the paper, and form distinct images on a sheet of paste-board placed behind the paper.

152. The quantities of light, received from a luminous body upon a given surface, are inversely as the squares of the distances of the surface from the luminous body.

Obs. The direct light of the sun is calculated to be equal to that of 6560 candles placed at the distance of one foot from the object; and that of the moon to the light of one candle at 7 1-2 feet distance, of Jupiter at 1620 feet, and of Venus at 421 feet.

Exp. The light, passing from a candle or any luminous body, will diverge as it proceeds, and will illuminate surfaces, which surfaces will be to each other as the squares of their distances from the candle. Thus, if at the distance of one foot, the candle illuminates any surface, at double the distance it will illuminate a surface equal to four times, and at the distance of three feet it will illuminate a surface equal to nine times, and, consequently, the surfaces illuminated are as the squares of the distances, 1, 2, and 3.

153. If rays proceed from a radiant point at an infinite distance, their divergency is so trifling, that they may be considered as parallel.

Obs. 1. Hence all the rays which could come from the centre, or any other given point, of the sun's surface, are considered as parallel at the immense distance of the earth.

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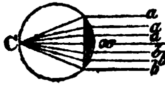

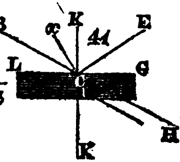
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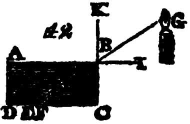
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2. To understand the nature of the convergency, divergency, and parallelism of rays of light, see fig. 40. A candle at C *diverges* rays of light towards *x*. They are said to *converge*, when considered as flowing from *x* towards C. And to be *parallel* as flowing from *x* towards *a* and *b*. C is the *focus* of the *converging* rays; and the imaginary focus of the diverging rays.

154. When rays of light pass *obliquely* out of one transparent medium into another, which is either more dense, or more rare, they are bent out of their former course, and they are then said to be REFRACTED.

155. Rays of light are always refracted *towards* a perpendicular to the surface in a *denser* medium; and this refraction is, more or less, in proportion as the rays fall, more or less, obliquely on the refracting surface.

Exp. Let B C, fig. 41, be supposed to be a ray of light passing out of air into water or glass, L G, at the point C; K K is a line drawn perpendicular to L G, and the ray B C, instead of proceeding along C H will in so passing, be bent towards the perpendicular C as long as C I.

156. On the contrary, when light passes out of a denser into a *rarer* medium, it moves in a direction *farther from* the perpendicular.

Exp. 1. Thus if the ray C I, fig. 41, pass out of the glass into air, it will not proceed in C x but in the direction C B, farther from F C than C.

2. Take a pan A B D C, fig. 42, with an upright side, into a dark room; let in, by means of a small hole in a window shutter, a ray of light G B, so as to fall upon the bottom of the pan at E; mark the spot E; then without moving the pan, fill it with water, and the ray now will not pass on to E, but will be refracted down to F. The candle G will answer as well as the direct rays of the sun.

3. If a shilling be stuck on the part F with wax, so that an eye at G cannot see it when the pan is empty, it will become visible the moment the pan is filled with water.

4. Take a glass goblet half full of water and put a shilling into it, then put a saucer or plate upon it, and holding it tight on, turn plate and glass together; a by-stander unacquainted with the laws of refraction, will suppose that he sees a shilling and a half crown; the one is seen by refraction through the water, the other by the rays after refraction at the surface.

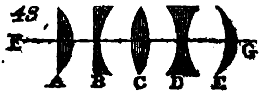
157. The *Angle of Incidence*, is that which is contained between the line described by the incident ray, and a line perpendicular to the surface on which the ray strikes, raised from the point of incidence. Thus in fig. 41, the angle B C K is the angle of incidence.

158. The *Angle of Reflection*, is that which is contained between the line described by the reflected ray and a line drawn perpendicularly to the reflecting surface at the point in which the ray passes through that surface. Thus, in fig. 41, E C K is the angle of reflection.

159. Availing themselves of the principle of *refraction*, philosophers have so contrived surfaces, that the perpendiculars to them constantly vary, and prod

new and important effects. This they have done by means of convex and concave glass *lenses*, so as to collect or disperse the rays of light which pass through it.

160. There are various kinds of lenses named according to their forms.



A *plano-convex lens* has one side flat, and the other convex, as A, fig. 43.

A *plano-concave* is flat on one side, and concave on the other, as B, fig. 43.

A *double-convex* is convex on both sides, as C, fig. 43.

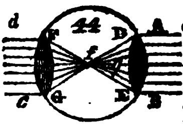
A *double-concave* is concave on both sides, as D, fig. 43.

A *meniscus* is convex on one side, and concave on the other, as E, fig. 43.

The *axis* of a lens, is a line passing through the centre: thus F G is the axis to all the five lenses.

161. If parallel rays fall upon a plano-convex lens, they will be so refracted as to unite in a point behind, called the principal focus, or focus of parallel rays.

Exam. Thus the parallel rays *a b*, fig. 40, falling upon the *lens* are refracted towards the perpendicular C *x*, and unite in a focus at C.



162. The distance from the middle of the glass to the focus, is called the *focal distance;* which focal distance in a plano-convex lens is equal to the diameter of the sphere of which the lens is a portion, fig. 40, and the focal distance of a double-convex lens, is equal to the radius of a sphere of which the lens is a portion, fig. 44.

163. All the parallel rays of the sun which pass through a convex glass as DE, are collected in its focus *f* and the force of the heat at the focus is to the common heat of the sun, as the area of the glass is to the area of the focus.

Illus. If a lens four inches in diameter collect the sun's rays into a focus at the distance of twelve inches, the image will not be more than one-tenth of an inch in diameter, the surface of this little circle is 1600 times less than the surface of the lens, and consequently the heat will be 1600 times greater at the focus than at the lens.

Cor. 1. Hence the construction of common burning-glasses, which are all double convex lenses.

2. Hence the reason why furniture has been set on fire by leaving a globular decanter of water incautiously exposed to the rays of the sun, which acts as a double convex lens.

164. If another double convex F G, fig. 44, be placed in the rays at the same distance from the focus, it will so refract the rays back again, that they *will* go out of it parallel to one another.

Illus. It is evident that all the rays, except the middle one, cross each other in the focus *f*, of course the ray D A, which is uppermost in going in, is the lowest in going out, as G *c.*

Exp. 1. If a candle be placed at *f*, the diverging rays between F G, will, upon going out of the lens, become parallel at *d c.*

2. If a candle be placed nearer the glass than the focus, the rays will *diverge*, after going through the lens.

3. If the candle be placed farther from the glass than the focus, the rays will *converge*, after passing through the glass, and meet in a point which will be more or less distant from the glass, as the candle is nearer to, or farther from, its focus.

4. When the rays meet, they will form an inverted image of the flame of the candle. Suppose B, a candle, fig. 46, and C a convex lens, then on a dark skreen D, the image A of the candle will be produced, and will be reversed, because the rays cross each other in passing through the lens.

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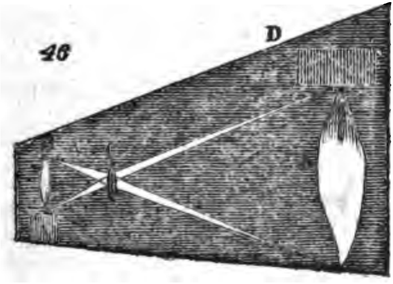

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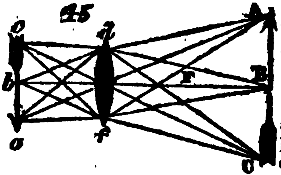

5. If an object A B C, fig. 45, be placed beyond the focus F of the glass *d e f*, some of the rays which flow from every point of the object on the side next the glass, will fall upon it, and after passing through it they will be converged into as many points on the opposite side of the glass, where the image of the whole will be formed, which will be inverted. Thus the rays flowing from A, as A *d*, A *e*, A *f*, will converge in the space *d e f*, and by meeting in *a* will there form the image of the point A; and so of those rays flowing from B and C, and of course of all the intermediate parts.

6. If the object A B C, be brought nearer the glass, the picture *a b c* will be removed to a greater distance from it.

7. The picture will be as much larger or less than the object, as its distance from the glass is greater or less than the distance of the object.

165. When parallel rays pass through a double concave lens, they will diverge after passing through the glass, as if they had come from a point in the centre of the concavity of the glass.

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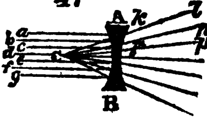


Exam. If the rays *a b c*, &c. fig. 47, pass through A B, and C be the centre of concavity, then the ray *a* after passing the glass, will go on in the direction *k l*, as if it had come from *c* and no glass in the way; the ray *b* will go on in the direction *m n*, and so on.

166. When parallel rays pass through a plano-concave lens, they diverge after passing through it, as if they had come from a point at the distance of a whole diameter of the glassy concavity.

167. The following are the principal phenomena of rays in connexion with various lenses;

Obs. 1. Through a *convex surface*, passing out of a rarer into a denser medium, *parallel rays* will become converging.

Diverging rays will be made to diverge less, to become parallel, or to converge, according to the degree of divergency before refraction, or of the convexity of the surface.

Converging rays towards the centre of convexity, will suffer no refraction.

Converging rays to a point beyond the centre of convexity, will be made more converging.

Converging rays towards a point nearer the surface than the centre of convexity, will be made less converging by refraction.

But when the rays proceed out of a denser into a rarer medium, the reverse occurs in each case.

2. When rays proceed out of a rarer into a denser medium, through a CONCAVE SURFACE if *parallel* before refraction, they are made to diverge.

If they are *divergent*, they are made to diverge more, to suffer no refraction, or to diverge less, according as they proceed from some point beyond the centre, from the centre, or from some point between the centre and the surface.

If they are *convergent*, they are either made less converging, parallel, or diverging, according to their degree of convergency before refraction:

And *the reverse*, in passing out of a denser into a rarer medium.

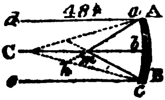
Exp. Most of the preceding propositions may be confirmed, in a room from which all external light is excluded, by placing a convex lens, or concave, fixed in a frame which moves perpendicularly upon an oblong bar of wood, or table, at different distances from a lighted candle placed perpendicularly on the same bar of wood, and receiving the images upon white paper. Upon this bar of wood, on one side of a line over which the convex lens is placed, let a line perpendicular to the last mentioned line be divided into parts, 1, 2, 3, 4, &c. each equal to the distance of the focus of parallel rays; and on the other side of the lens, let a line be divided in the same manner, and let the first division, which is farther from the lens than the focus, be subdivided into parts respectively, equal to 1-2, 1-3, 1-4, &c. of the distance of the focus of parallel rays: if a candle be placed over the division 2, it will form a distinct image on a paper held over the division 1-2: if a candle be over 3, the image will be at 1-3, &c. whence it appears, that the distances of the correspondent foci vary reciprocally; or by holding a large double convex lens, or burning glass, in the sun's rays, and receiving the image on white paper, or other substance at different distances.

168. When rays of light strike against a smooth surface, and are sent back from it, they are said to be RE-

FLECTED, and the ray that comes from any luminous body, and falls upon the reflecting surface, is called the *incident ray*.

Exam. If L G, fig. 41, be a reflecting surface, as a looking glass, then B C is the incident ray, and C E is the *reflected* ray.

159. The *angle of incidence* is that which is contained between the incident ray, and a perpendicular to the reflecting surface in the point of reflection, as B C K, fig. 41. The *angle of reflection* is that contained between the perpendicular and the reflected ray, as K C E, fig. 41. And the angle of incidence and reflection are always equal.



Obs. 1. Let the lines C *a* and C *c*, fig. 48, be drawn, which are perpendicular to the concave surface *a c*, and it will be found, that the angle of incidence *d a c*, is equal to the angle of reflection C *a m*, and *e c* C is equal to C *c m*.

2. Sir Isaac Newton explains the cause of reflection by supposing, that light, in its passage from the luminous body, is disposed to be alternately reflected by, and transmitted through any refracting surface it may meet with; that these dispositions, which he calls fits of easy reflection and easy transmission, return successively at equal intervals; and that they are communicated to it, at its first emission out of the luminous body it proceeds from, probably by some very subtle and elastic substance diffused through the universe, in the following manner: As bodies falling into water, or passing through the air, cause undulations in each, so the rays of light may excite vibrations in this elastic substance. The quickness of these vibrations depending on the elasticity of the medium, (as the quickness of the vibrations in the air, which propagate sound, depend solely on the elasticity of the air, and not upon the quickness of those in the sounding body,) the motion of the particles of it may be quicker than that of the rays; and, therefore, when a ray, at the instant it impinges upon any surface, is in that part of a vibration which is contrary to its motion, it may be reflected. He farther supposes, that when light falls upon the first surface of a body, none is reflected there, but all that happens to it there is, that every ray that is not in a fit of easy transmission, is there put into one, so that when they come at the other side, (for this elastic substance, ily pervading the pores of bodies is capable of the same vi-

brations within the body as without it) the rays of one kind shall be in a fit of easy transmission, and those of another in a fit of easy reflection, according to the thickness of the body, the intervals of the fits being different in rays of a different kind.

3. This doctrine of fits does not accord with the general simplicity of nature, or of the other parts of this great man's philosophy. It seems far more reasonable to consider the phenomena of light, as being produced by vibrations of an universal medium, the intervals between the vibrations corresponding with the fits above supposed. Such ideas of vibrations correspond too, with the general analogies of nature in other particulars.

170. The following are the chief phenomena of reflected rays:

1. *Parallel* rays reflected from a CONCAVE surface, are made converging.

Converging rays falling upon a *concave* surface, are made to converge more.

Diverging rays falling upon a *concave* surface, if they diverge from a focus of parallel rays, become parallel.

If from a point nearer to the surface than that focus, they diverge less than before reflection.

If from a point between that focus and the centre, they converge after reflection to some point, on the contrary side of the centre, and farther from the centre than the point from which it diverged.

If from a point beyond the centre, the reflected rays will converge to a point on the contrary side, but nearer to it than the point from which they diverged.

If from the centre, they will be reflected thither again.

Exp. Place a concave mirror at proper distances from an open orifice, or a convex, or a concave lens, through which a beam of solar rays passes, and verify the preceding propositions.

2. *Parallel* rays reflected from a CONVEX SURFACE, are made diverging.

Diverging rays reflected from a *convex* surface are made more diverging.

Converging rays reflected from a *convex* surface, if they tend towards the focus of parallel rays, will become parallel.

If to a point nearer the surface than that focus, will converge less than before reflection.

If to a point between that focus and the centre, will diverge as from a point on the contrary side of the centre farther from it than the point towards which they converged.

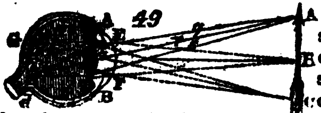
If to a point beyond the centre, they will diverge as from a point on the contrary side of the centre nearer to it than the point towards which they converged.

And if towards the centre, they will proceed on reflection, as far from the centre.

Exp. Illustrate the three preceding propositions by receiving upon a convex mirror, a solar ray passing through an open orifice, or concave, or convex lens.

OF THE EYE.

171. The eye is composed of three *coats*, covering one another, and inclosing different substances called *humours*. The three coats are called the *sclerotica*, the *choroides*, and the *retina*. The three humours are the *aqueous*, the *chrystalline* and the *vitreous*.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Illus. A B G fig. 49, is a section of the globe of the eye, the three circles represent the three coats; the outer one is the *sclerotica*, but the part AEFB, is called the *cornea*. The middle circle is the *choroides*, the fore part of which is called the *iris*, and the inner circle represents the *retina*, which serves to receive the images or objects produced by the refraction of the different humours of the eye. The aqueous humour fills up all the space A, E, F, B, *x*; *y s* is the chrystalline humour in the form of a double convex lens; and the vitreous humour occupies all the interior part of the eye *m n*, behind the chrystalline. From the hinder part of the eye, proceeds the optic nerve *d*, which conveys to the brain the sensations produced on the retina.

Obs. Mr. Harris has given a table of the dimensions of the parts of the human eye, of which the following are the principal particulars in parts of inches.

Diameter from the cornea to the choroides	.95
Radius of the cornea - - -	.335
Distance of the cornea from the first surface of the chrystalline - - -	.106
Radius of the first surface of the chrystalline	.331
Radius of the back surface of the chrystalline	.25
Thickness of the chrystalline - -	.373

172. Objects are seen in consequence of the images being painted on nerves, or *retina*, at the back of the

eye; and though the images of objects are painted on the retina inverted, yet they are seen erect by the habit of the mind.

Illus. As the object A B C, fig. 49, sends out rays that fall on the *cornea* of the eye between E and F, and by passing on through the pupil and humours, they will be converged to as many points on the *retina*, and will there form a distinct inverted picture, *c b a* of the object. Thus the pencil of rays *q r s*, that flows from A, will be converged to the point *a* on the retina; those from B, will be converged to the point *b*; those from C to the point *c*; and so of all the intermediate points; by which means the whole picture *a b c* is formed, and the object is made visible.

Exp. Take off the *sclerotica* from the back part of the eye of an ox, or other animal, and place the eye in the hole of the window shutter in a dark room, with its fore part towards the external objects; a person in the room will, through the transparent coat, see the inverted image painted upon the *retina.*

Obs. 1. It is found from experience, that when the image upon the retina is bright, the object is clearly seen; and when the image is faint, the object appears faint; also, that when the image is distinct, the object is seen distinctly; and when the image is confused, the object appears confused. Hence it may be concluded, that these images are the cause of vision.

2. It is manifest, that a different conformation of the eye, or some parts of the eye, is necessary for distinct vision at different distances. Some think the change is in the length of the eye; others, that it is a change in the figure or position of the chrystalline humour; and others, that it is a change in the cornea; but any of these changes would produce the effect.

173. Dimness of sight generally attends old people, and arises either (1) by the eyes growing flat, and not uniting the rays exactly on the retina: or (2) by the humours losing their transparency in some degree, which makes every object appear faint and indistinct.

174. If the chrystalline humour has either too much or too little convexity, the sight will be defective, owing to the image being formed before or behind the retina.

Obs. In persons who are short-sighted, the humours of the eye are too convex, and bring the rays to a focus, before they reach the retina, unless the object be brought near to it; in which case the image is cast farther back. In others, the humours of the eye have so little convexity, that the focal point lies behind the *retina;* whence, unless the object is removed to a greater distance from the eye, the vision will be indistinct.

175. When the diameter of an object is given, its apparent diameter to the eye, is inversely as its distance from the eye, and the apparent diameter is the angle which it subtends to the eye; so that its apparent size is as the angle which it subtends to the eye.

Obs. 1. The angle subtended as the least visible object, called by the writers on optics, the *minimum visible*, cannot be accurately ascertained, as it depends upon the colour of the object, and the ground upon which it is seen; it depends also upon the eye. Mr. Harris thinks the least angle for any object to be about 40 seconds; and at a medium, not less than two minutes. To the generality of eyes, the nearest distance of distinct vision, is about 7 or eight inches. Taking 8 inches for that distance, and 2 minutes for the least visible angle, a globular object of less than the three-hundredth part of an inch cannot be seen.

2. The apparent diameter of an object is as the diameter of its image upon the retina; and the diameter of the image, when the object is given, is *inversely* as the distance of the object; therefore the apparent diameter of the object is also *inversely* as the distance of the object. The same may be proved of any apparent length whatsoever.

3. Hence the apparent diameter of an object may be magnified in any proportion; for the *less* the distance of the eye from the object, the greater will be its apparent diameter. But without the help of glasses, an object brought nearer the eye than about five inches, though it appears larger, will at the same time appear confusedly.

4. Many deceptions in vision arise from the above consideration. We judge of the *distance* of any object by the visible length of the plane, which lies between the eye and the object. When this method fails us, we compare the known magnitude of the object with its present apparent magnitude; or we compare the degrees of distinctness with which we see the several parts of an object; or we observe whether the change of the apparent place of an object when viewed from different stations, or its *parallax*, be great or small, this change being always in proportion to the distance of the object. On this principle, we may judge of the distance of a near object, by

observing the change which is made in its apparent situation, upon viewing it successively with each eye singly. Or, since it is the difference of the apparent place of an object, as viewed by each eye separately which makes an object to be seen double unless we turn both eyes directly towards it, and since in doing this, where the distance is very small, we turn the eyes very much towards each other, and less at a greater distance; the different sensations accompanying the different degrees in which the eyes are turned towards each other, afford by habit, a rule for judging of the distance.

5. In objects placed at such distances as we are used to, and can readily allow for, we know, by experience, how much an increase of distance will diminish their apparent *magnitude*, and, therefore, instantly conceive their real magnitude, and neglecting the apparent, suppose them of the size they would appear if they were less remote; but this can only be done, where we are well acquainted with the real magnitude of the object; in all other cases, we judge of magnitudes by the angle which the object subtends at the known, or supposed, distance; that is, we infer the real magnitude from the apparent magnitude in comparison with the distance of the object.

OF COLOURS.

176. Rays of light are *differently refrangible*, or *refractible*, that is to say, some are more easily turned out of their course than others;—and are *differently reflexible*, when some are more easily reflected than others.

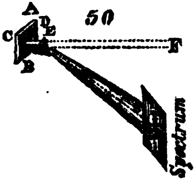
Obs. The powers of rays in regard to their refrangibility or reflexibility, are ascribed, on the hypothesis of their being particles like sand, to the different *momenta* of the particles; and on the hypothesis of their being simple vibrations like undulations of water, to the vivacity or acuteness of the vibrations. It seems, indeed, evident, that the rays which are turned the most out of their course by a refrangible medium have *less* powers or momenta, than those which are the least diverted from their course. Different colours are therefore simply the effect of the different perceptions produced on the optic nerves by the different forces or the action of the rays, the red being the most forcible, and the violet the least.

177. Light is called *homogeneous*, when all the rays are equally refrangible; and *heterogeneous*, when some

rays are more refrangible than others. The *colours* produced by homogeneous rays, are called *primary* or *simple* colours; those of heterogeneous, *secondary* or *mixed*.

178. To examine the different colours of a ray of light, a small hole must be made in the shutter of a dark room, and the ray must fall upon a prism in an oblique direction.

Obs. Prisms are commonly made of solid glass, but students who do not possess one of this kind, may easily make a substitute. Take three pieces of plate glass, (the kind of which looking glasses are made) each four, or six inches long and two or three inches wide; get made of tin a frame consisting of the two ends in the exact shape of the three pieces of glass placed in the form of a triangle, with a strip of tin running from each angle of one end to the angles or corners of the other. These strips are bent so as to receive the two edges of the glass plates. When the frame is complete, except the soldering in of one of the ends, fix the glass plates in their places, and then have the end soldered. The tin forming the ends is turned up so as to receive the plates, and one of the ends is furnished with a spout to pour in water. When this is done, the vessel is made water tight, by stopping with putty all the crevices between the glass and tin. The prism is then filled with clear water by the spout and corked up.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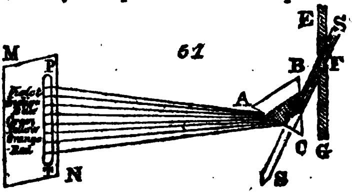
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Illus. 1. Let A B, figure 50, represent part of the shutter of the window of a room, in which no light enters except through the hole C. If the light of the sun be received upon a screen at any distance from the hole, as at E, a circular luminous spot will be formed upon the screen, which is larger in diameter than the hole at C. Place a glass prism E before the hole, so that the light may pass through in a direction perpendicular to the axis of the prism; and instead of going straight from E to F, the light which comes through the hole, will, by passing through the prism, be bent and dispersed in such a manner, as to form a coloured spectrum or image G H upon a screen which may be situated at any distance from the prism, but below the straight direction C F. The length of the spectrum G H is equal to about five times its breadth, and is terminated by semicircular ends. The highest part G is of a beautiful *red* colour, which, by insensible shades, degenerates into an *orange*, then a *yellow*, a *green*, a *blue*, an *indigo*, and a *violet*, which is the colour next to H, viz. at the lowest part of the spectrum.

2. Or in fig. 51, let E G be a shutter, F a hole, S S a ray or direction of solar light, A B C a glass prism, then the light falling on B C will be unequally refracted to the wall M N, and produce the coloured spectrum P T. The violet being the most, and the red the least turned out of their course.

179. If the whole spectrum be divided into 360 parts, the *red* will occupy 45 of them, the *orange* 27, the *yellow* 48, the *green* and the *blue* 60 each, the *indigo* 40, and the *violet* 80. By mixing the seven primitive colours in these proportions, a dusky white is obtained. And the seven colours are reducible to three, viz. the red, blue, and yellow.

Exp. Paint on a circular board the seven colours in their proper proportions, and then whirl the board with great velocity, it will appear of a dirty white. If the colours were more perfect and accurately defined, the white would appear more perfect also.

180. The colours of homogeneous light can neither be changed by refraction nor reflection, and the whiteness of the sun's light arises from a due mixture of all the primary colours.

Exp. 1. Let a beam of homogeneous light pass through a round hole in a pasteboard, and then be refracted by a prism on the other side, the colour of the rays will remain the same.

2. Red lead, viewed in homogeneous red light, will be red, but if placed in green, or any other homogeneous light, it will take the colour of the rays which fall upon it.

181. The colours of all bodies are either the simple colours of a homogeneous light, or such compound colours as arise from the mixture of homogeneous light.

Obs. 1. Each sort of light having a peculiar colour of its own, which no refraction or reflection can alter, since bodies appear coloured only by reflected light, their colours can be no other than the colour of some single homogeneous light, or of a mixture of different sorts of light.

2. When the thickness of the particles of a body is such, that one sort of colour is reflected, other colours will be transmitted, and therefore the body will appear of the first colour. And, in general, a less thickness is found to be necessary to reflect the most refrangible rays, as violet and indigo, than those which are least refrangible, as red and orange. Sir I. Newton, from a variety of experiments on light and colours, concludes that every substance in nature is transparent, provided it may be sufficiently thin.

3. Mr. Delval has, however, by a great variety of well conducted experiments, shewn that colours are exhibited, not by reflected, but by transmitted light. This he proved by covering coloured glass, and other transparent coloured media, on the further surface, with some substance perfectly opaque, when he found that they reflected no colour, but appeared perfectly black. He concludes, therefore, that, as the fibres of mineral and animal substances are found, when cleared of heterogeneous matters, to be perfectly white, the rays of light are reflected from these white particles, through the coloured media with which they are covered; that these media serve to intercept and impede certain rays in their passage through them, while a free passage being left to others, they exhibit, according to these circumstances, different colours.

4. Mr. Delval concludes, (1,) That the colouring particles do not reflect any light. (2,) That a medium, such as Sir I. Newton described, is diffused over the anterior and further surfaces of the plates, whereby objects are reflected equally and regularly as in a mirror.

5. To determine the principle on which opaque bodies appear coloured, it must be recollected, first, that all the coloured liquors, appear such only by transmitted light; and, secondly, that these liquors, spread thinly upon a white ground, exhibited their respective colours; he therefore concludes, that all coloured bodies, which are not transparent, consist of a substratum of some white substance, which is thinly covered with the colouring particles.

6. On extracting, by means of spirits of wine, the colouring matter from the leaves, wood, and other parts of vegetables, he found that the basis was a substance perfectly white. He also extracted the colouring matter from different animal substances, as flesh, feathers, &c. when the same conclusion was obtained. Flesh consists of fibrous vessels, containing blood, and is perfectly white when divested of blood by ablution, and the red colour proceeds from the light which is re-

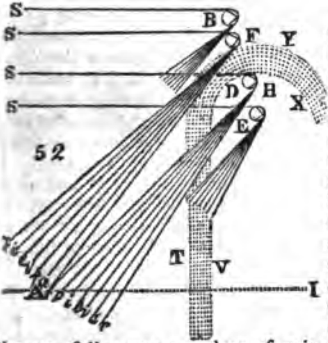
flected from the white fibrous substance through the red transparent covering formed by the blood. The result was the same from an examination of the mineral kingdom.

OF THE RAINBOW.

182. *The Rainbow* is a meteor in form of a party-coloured arch, or semicircle, exhibited only at the time when it rains. It is always seen in that point of the heavens which is opposite to the sun, and is occasioned by the refraction and reflection of his rays in the drops of falling rain. There is likewise, though not always distinctly visible, a secondary, or much fainter rainbow, investing the former at some distance.

Obs. When the sun shines upon drops of rain as they are falling, the rays which come from those drops to the eye of the spectator, after one reflection and two refractions, produce the innermost, or PRIMARY RAINBOW.

Fig. 52, representing the *refraction* and *reflection of light falling on drops of water, in the innermost or primary rainbow.*



Let TFY be the innermost or primary rainbow, the outer part of which TFY is red, and the inner part VDX violet, and the intermediate parts reckoning from the red to the violet, orange, yellow, green, blue, indigo. Suppose the spectator's eye at A, and let AI be an imaginary line from the centre of the sun to the eye of the spectator. If a beam of light S coming from the sun, falls upon any drop of rain F, and the rays which emerge at F, make an angle FAI of 42 degrees 2 minutes with the line AI, these rays make the same angle with the incident rays, and consequently are red.* Hence the drop F will appear red; for all the other rays which emerge from F, and would be effectual if they fell upon the eye, being refracted more than the red rays, will pass above the eye. If another beam of light S falls upon the drop D, and the effectual rays emerging at H, make an angle of 40° 17′ with the incident rays, the drop D will be of a violet colour, for all the other rays which emerge from H, and would be effectual if they came to the eye, being refracted less than the violet rays, will pass below the eye. The intermediate drops between F and D will, for the same reasons, be of the intermediate colours. And that which has been proved concerning the drops in the line F D, may be shewn in any other set of drops in which the angles made by the emerging and incident rays are equal. Thus, wherever a drop of rain is placed, if the angle which the effectual rays make with A I is equal to the angle F A I, or is 42° 2′, any such drop will appear red. If F A I were turned round upon the line A I, so that one end of this line should always be at the eye, and the other at I opposite to the sun, in this revolution the drop F would describe a circle, of which I would be the centre, and T F Y an arc. And since in this revolution the angle F A I continues the same, if the sun was to shine upon this drop as it revolves, the effectual rays would make the same angle with the incident rays, in whatever part of the arc T F Y the drop may happen to be; and, consequently, in whatever part of the arc the drop F is, it will appear red. Now as innumerable drops are falling at once in right lines from the cloud, whilst one drop is at F, there will be others at T Y, and every other part of the arc, which will appear red in the same manner that F would have done in the supposed circular revolution. Therefore, when the sun shines upon the rain, there will be a red arc T F Y produced opposite to the sun. In like manner a violet arc V D X will be produced, and other intermediate colours, which will together make up the primary rainbow. At the eye at A the rays are divided from R red to P purple, just as they present themselves to the eye in nature.

Exp. Let a glass globe, filled with water, be exposed to the rays of the sun: let the eye of the spectator be so situated, that the least refracted ray from the drop, coming to the eye, shall make an angle of about 42° with the line passing through the eye and the sun, the red rays only will be seen; if the place of the eye be changed, so as to enlarge this angle, the red will disappear; but if the angle be lessened, the colours of the more refrangible rays will appear.

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* The angle which the effectual red rays make with the incident rays, is found to be 42° 20′, that of the violet rays 40° 17′.

Obs. 1. Cascades and fountains, whose waters, in their fall, are divided into drops, will exhibit rainbows to a spectator, properly situated, during the time of the sun's shining. This appearance is also seen by moon-light, though seldom sufficiently vivid to render the colours distinguishable. Coloured bows have been seen on grass formed by the refraction of the sun's rays in the morning dew.

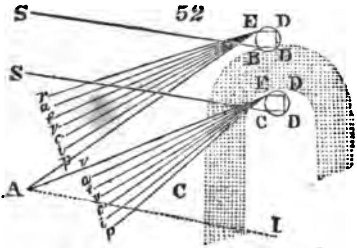
2. Artificial rainbows may be produced by a candle light on the drops of water ejected by a small fountain, or jet d'eau, or from the stream emitted from an eolipile. But the most natural and pleasing is by means of the air fountain, the jet of which is perforated with a great number of very fine holes from which the water spouts so as to form a kind of fluted column. The rainbow is formed by the sun's rays, for the spectator has to place the spouting streams directly in the sun's beams, with his own back to the sun, and being in a direct line with the sun and the centre of the jet, by stooping his head to a certain degree, he will discover the beautiful appearance of the natural prismatic colours, and a small rainbow, on the same principle as those which are seen in the time of rain and sunshine.

183. The primary rainbow can never be a greater arc than a semicircle.

Since the line *a i* fig. 52, is drawn from the sun through the eye of the spectator, and through *i* the centre of the rainbow, this centre is always opposite to the sun. And since the angle *f a i* is an angle of 42° 2′, *f*, the highest part of the bow is 42° 2′ from *i* its centre. If, therefore, the sun is more than 42° 2′ above the horizon, *i*, which is opposite to it, must be more than 42° 2′ below the horizon, and no primary rainbow will be seen. As much as the altitude of the sun is less than 42° 2′, so much will the highest point *f* of the rainbow be above the horizon; and when the sun is in the horizon, *i*, the centre of the bow will also be in the horizon on the opposite side, and half the circle will be visible; but when the sun is set no bow can be seen.

184. When the light falls upon the under parts of drops of rain, some of it, after two reflections and two refractions, comes to the eye of the spectator who had his back towards the sun, and his face towards the drop. An

those rays which are parallel to one another, after they have been once refracted, and once reflected in a drop of rain, will be coloured, and produce an exterior rainbow, when they emerge after two refractions and two reflections.



When the sun shines upon a drop of rain E fig. 52, in the outer edge of the secondary rainbow CBD, the effectual violet ray FA makes an angle EAI of 54° 7′ with AI a line drawn from the sun through the eye of the spectator, and therefore makes the same angle with the incident ray S B. Therefore if the spectator's eye is at A, all the rays except the violet, will make a less angle with A I than E A, and fall above the spectator's eye. In like manner it may be shewn, that from the drop F only red rays will come to the spectator's eye, the rest falling below it; and that the rays emerging from the intermediate drops between E and F, and coming to A, will emerge at intermediate angles, and present to the eye the intermediate colours. If EAI be conceived to turn round upon the line A I, in such a revolution of the drop E, the angle E A I would remain the same, and consequently the emerging rays would make the same angle with the incident rays. But in such a revolution the drop E would describe a circle, of which I would be the centre, and C B D an arc. Consequently, since the emerging rays make the same angle with the incident ones when the drop is at any other part of the arc as at E, the colour of the drop will be violet to an eye placed at A, in whatever part of the arc the drop is placed. Now since there are innumerable drops of rain falling at once, whilst one drop is at E, there will be others in all parts of the arc, which will all appear violet-coloured, for the same reason that E would have appeared of this colour in any other part of the arc. In like manner as the drop F, appears red at F, and at any part of the arc FD, so will any other falling drop when it comes to any part of that arc. The intermediate arcs are formed in the same manner with the violet arc CBD, and the red arc FD: and thus the whole secondary rainbow is produced.

185. The colours of the secondary rainbow are fainter than those of the primary, and are ranged in the contrary order.

Obs. 1. The angle which the violet rays make with the incident ones is found to be 54° 7′, and that of the red rays 53° 57′. At every reflection many rays pass out of the drop without being reflected; consequently, the secondary rainbow which is produced after two reflections, is formed by fewer rays than the first, which is produced after one reflection.

2. Again, in the primary bow, the violet rays, when they emerge effectually, make a less angle with the incident rays, and, therefore, with the line AI, than the red rays. But the rays are here only once reflected, and the angle which the effectual rays make with A I is the distance of the coloured drop from I, the centre of the bow. Therefore, the violet arc in the primary bow will be nearer to the centre of the bow than the red arc, that is, the innermost colour will be violet, and the outermost red. But in the secondary rainbow, the rays are twice reflected; and the violet rays, which emerge so as to be effectual after two reflections, make a greater angle with the incident rays, that is, with the line A I, than the red ones: which angle is the distance of the violet arc from I the centre of the bow. Therefore, the violet arc in the secondary bow will be farther from the centre of the bow than the red arc; that is, the outermost colour is violet, and the innermost red.

OF OPTICAL INSTRUMENTS.

186. A *mirror* or *speculum* is an opaque body, whose surface is finely polished, so that it will reflect the rays of light which fall upon it, and thus represent the images of objects.

Obs. They are made of metal, or glass polished on one side and silvered on the other. There are three kinds of mirrors, viz. the *plane*, the *convex*, and the *concave*.

187. *Concave* glasses are necessary to those whose eyes are too convex.

Exp. If the parallel rays, fig. 48, *d a*, C *m b*, and *e c*, fall upon the concave mirror A B, then *d a* will be reflected along *a m*, C *b* will be reflected along *b m*, and *e c* along *c m*; of course they all meet in *m*: and *m b* is found to be equal to *m* C, or half C *b*.

Illus. When the eye is too round, the rays proceeding from objects are converged to a focus before they get to the retina; to remedy this, a concave glass is used, because the property of this is, to *disperse* the rays which prevent them from coming to a focus so soon as they otherwise would.

188. *Convex* glasses are necessary to those whose eyes are too *flat.*

Illus. When the eye is too flat, the rays proceeding from objects do not converge to a focus so soon as they reach the retina; a convex glass has the property of converging the rays, and of course bringing them to a focus sooner than they otherwise would.

Obs. Were there no other use of the science of dioptrics than that of spectacles, the advantage that mankind receive thereby is inferior to no other benefit, not absolutely requisite to the support of life. For as the sight is the most noble and extensive of all our senses; as we make the most frequent use of our eyes in all the actions and concerns of life: surely that instrument which relieves the eyes when decayed, and supplies their defects, must be estimated as the greatest of all advantages. Forlorn, indeed, must have been the situation of many young, and almost all old people, before this admirable invention.

189. MICROSCOPES are instruments for viewing small objects; and they apparently magnify objects, because they enable us to see them nearer than with the naked eye, without affecting the distinctness of vision.

Exp. Take a piece of brown paper and make a pin-hole in it, then bring the eye close to the hole, and the paper within two or three inches of any small print or object, and it will be apparently much magnified, though without the paper the letters would at that distance be wholly illegible.

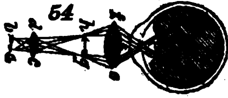
Obs. All that the hole or microscope effects is to enable us to see an object *distinctly* much nearer to the eye than it could be seen by the eye unaided. The *magnifying* power is as the proportion of the distance, at which we usually view objects, to that at which the microscope enables us to see them or their true images.

190. There are three kinds of microscopes, the *single*, the *compound*, and the *solar.*

The *single* microscope, is a small double convex lens, having the object placed in the focus, and the eye at the same distance on the other side. Its magnifying power is found by dividing seven inches, the least distance at which an object can be seen distinctly by the naked eye, by the focal distance of the lens.

Exp. If the focal distance of the lens be only the 1-4 of an inch, then the diameter of an object will be magnified 28 times (because 7 divided by 1-4 is the same as multiplying 7 by 4,) and the surface will be magnified 784 times.

The *compound* microscope consists of an object-glass and an eye-glass. Its power is in proportion as the image is larger than the object, and also according as we are able to view it at a less distance. There are generally two eye-glasses, by which means the object is less magnified, but more of it is seen.



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Illus. 1. The object to be viewed is *a b*, fig. 54, *c d* is the object glass, and *e f* the eye glass. The small object *a b*, is placed a little beyond the focus of *d c*, the rays will converge and the image be formed at *g h*. The image, therefore, and not the object, is viewed by the eye, B A E, through the lens *e f*, which is so placed that the image *g h* may be in its focus, and the eye about the same distance on the other side; the rays on each pencil will be parallel after going out of the eye-glass at *e f*, till they come to the eye at *k*, where they will begin to converge by the refractive humour of the eye, and having crossed each other and passed through the chrystalline and vitreous humours, they will form the inverted image A B on the retina.

5. If the image *g h* is 4 times larger than the object *a b*, and by the help of the eye-glass we can view it 7 times nearer than we could by the naked eye, on both these accounts the diameter of the object will be magnified 4 times 7, or 28 times; and the surface 28 times 28, or 784 times.

The *solar* microscope depends on the sun-shine, and is used in a darkened room. It is composed of a tube, a looking-glass, a convex lens, and a single microscope. The sun's rays are reflected by the *looking-glass* through the tube upon the object, the image of which is thrown upon a white screen, sheet, &c. placed at a distance to receive it.

Obs. The magnifying power of the instrument is in proportion as the distance of the image from the object-glass is greater than the object itself is from it. If the distance of the object from the object-glass be 1-4 of an inch, and the distance of the picture be ten feet, or 120 inches, then the object is magnified in length 480 times, or in surface 230,000.

191. TELESCOPES are used for viewing objects at a great distance; of these, there are two kinds, the *refracting* and *reflecting*.

192. It is the sole business of all Telescopes to enable the eye to see the object under an enlarged angle. For this purpose, a new image of an object is produced by the object-glass of the telescope, and then this image is viewed by means of the eye-glasses.

Obs. As the object or its image is seen by the eye under an enlarged angle, or in the same way in which it would be seen if much nearer to the eye, so the first impression conveyed to the mind by a telescope, is that of bringing the object nearer, which is only another mode of declaring that it is enlarged, or seen under a large angle.

193. The apparent diameter of an object seen through a telescope, is to the apparent diameter of the same object seen by the naked eye, as the distance of the image from the object-glass is to its distance from the eye-glass.

Illus. If the image, formed by the object-glass, were received upon paper, the apparent diameter of the object seen by the naked eye at the station of the object-glass, would be equal to the apparent diameter of the image seen from the same station, and the apparent diameter of the image will of necessity be inversely as the distance of the eye from it, or as the focal distance of the object-glass. If the eye then be placed at the station of the eye-glass, consequently, the image will appear to the eye in that nearer station bigger than at the object-glass in the inverse ratio of the distances. Therefore the apparent diameter of the object seen with the telescope, is to the diameter of the same object seen by the naked eye at the station of the object-glass, as the distance of the distinct image from the object-glass is to the distance from the eye-glass, that is, as the focal distance of the object-glass is to the focal distance of the eye-glass; consequently, if the former be divided by the latter, the quotient will express the magnifying power; thus, if the telescope will magnify ten times in diameter, the focal distance of the object-glass is *ten* inches, and that of the eye-glass *one* inch.

Obs. 1. Consequently, a telescope will not magnify an object, unless the focal distance of the object-glass is greater than the focal distance of the eye-glass. And of course the object-glass of a telescope should be less convex than the eye-glass.

2. An object will be equally magnified by two telescopes of very different lengths, if the ratio of the focal distances of the object-glass and the eye-glass be the same in each.

3. And if a telescope is inverted, objects seen through it will be diminished; for the object-glass which has the greater focal distance then becomes the eye-glass, and it reverses the proportion.

4. The visible area, or space which may be seen at one view through a telescope, is as the area of the eye-glass.

5. The brightness of an object seen through a telescope depends upon the area of the object-glass, but not the visible area.

6. The distance of the eye from the eye-glass should be equal to the principal focal distance of the eye-glass.

194. A Telescope, to shew objects in their natural posture, has three eye-glasses. The two additional lenses simply give an erect position to objects. The three eye-glasses have all their focal distances equal, and the magnifying power is found as before, by dividing the focal distance of the object-glass by the focal distance of one of the eye-glasses.

195. *Galileo's telescope* consists of a convex object-glass and a concave eye-glass, so placed that the distance between them is the difference of their focal distances.

Obs. From a distant object, rays fall upon the convex object lens, from which they will proceed towards the focus of that lens. But the concave eye-glass renders the converging rays parallel when they reach the eye; whence an image will be formed upon the *retina*. And the pencils of rays being made more diverging by passing through the concave lens, the visible image is seen under a larger angle than the object, and appears magnified. Also, because the pencils which form the image only cross one another once, the image appears erect.

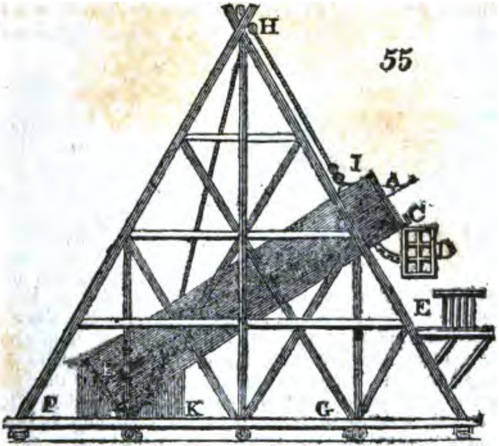
196. *Newton's telescope* consists of a tube, towards the end of which a concave mirror is placed. The converging rays, before they reach the focus, are made to fall upon a plane mirror placed at an angle of 45 deg. and thrown upwards to the focus of a convex lens fixed

in the upper side of the telescope, through which the eye looks down on the object.

197. *Gregory's telescope* consists of a tube on which a concave mirror, having a hole in its centre is placed. Any parallel rays from an object falling upon this mirror, will, after reflection, form an inverted image at its focus. This image, however, is intercepted by a smaller mirror, which reflects it back to an eye-glass in the hole of the large mirror, through which the observer views the object.

Obs. 1. In the telescopes made by Dr. HERSCHEL, the object is reflected by a mirror, as in the Georgian telescope, and the rays are intercepted by a lens at a proper distance, so that the observer has his back to the object, and looks through the lens at the mirror. The magnifying power will be the same as in the Newtonian telescope, but there being no second reflector, the brightness of the object viewed in the Herschel telescope is greater than that in the Newtonian telescope.

2. The tube of Dr. Herschel's grand telescope, is 39 feet 4 inches in length, 4 feet 10 inches in diameter, every part of which is made of iron. The concave surface of the great mirror is 48 inches of polished surface in diameter, its thickness 3 1-2 inches, and its weight is upwards of 2000 lbs. This noble instrument was, in all its parts, constructed under the sole direction of Dr. Herschel: it was begun in the year 1785, and completed Aug. 28, 1789, on which day was discovered the sixth satellite of Saturn. It magnifies 6000 times.



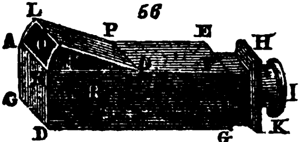
3. **ABC is a ray of light, reflected by the great Speculum B, to the eye-glass C. D is a chair for the observer. E a moveable gallery for spectators. FG a smooth base for the frame to turn on. H and I pulleys to move the instrument. K are rooms for assistants.**

4. **Dr. Priestley observes, that the easiest method of finding the magnifying power of any telescope, by experiment, is to measure the diameter of the aperture of the object-glass, and that of the little image of it, which is formed at the place of the eye. Another method, is to observe at what distance you can read any book with the naked eye; and then removing the book to the farthest distance at which you can distinctly read it by the help of the telescope, the greater distance divided by the less, gives the power of the telescope.**

5. **Dolland's achromatic telescope by a disposition and mixture of crown and flint object-glasses, destroys the colours which arise in any single object-glass.**

198. The *Camera Obscura* is made by fixing a convex glass in a hole of a window shutter, and, if no light enters the room but through the glass, the pictures of all objects on the outside may be seen in an inverted position on a white paper placed in the focus of the lens. If the

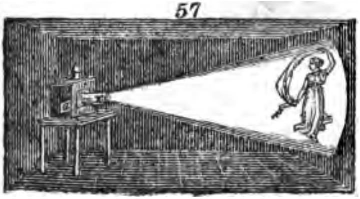
convex lens be placed in a tube in the inside of a box, within which is a looking-glass sloping backwards, t is called a *portable camera obscura.*


56

Illus. Fig. 56, represents a box consisting of two parts. The outer ABCDEFG has a shutter or cover LNPQ, which moves round a hinge PQ, and when open, as in the figure, it carries two lateral boards which serve to exclude the external light as much as possible from the rough glass O, upon which the observer is to look. The foreside of the box is wanting, and in that aperture another narrower box EHIKG slides: this box wants the inner side, and has a convex glass lens fixed at I. If this machine be turned with the lens I towards any objects that are well illuminated, an inverted picture of them will be formed within the box on the side ABCD, and that picture may be rendered distinct by moving the sliding box EH GK in or out, in order to adjust the focus according to the distance of the objects. At the back part of the box a flat piece of looking glass is situated at an inclination of half a right angle, as it is shewn by the dotted lines B R; in consequence of which the rays of light fall upon the looking glass, and are reflected upwards to the rough glass O. The picture then is formed upon that rough glass, and will appear erect to a spectator situated behind the box, and looking down upon the glass O, from which a drawing may be made.

199. The *Magic Lantern* is an instrument used for magnifying paintings on glass, and throwing their images upon a white screen in a darkened chamber. (See figs. 57 and 58,) And the magic lantern becomes the *Phantasmagoria* when the glass slides are rendered opaque between the objects.

57



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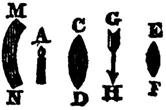
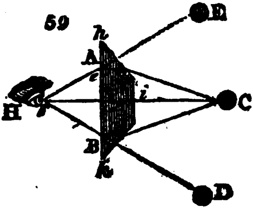


Illus. Fig. 57 represents the machine with the effect it produces. Fig. 58 shews the internal parts of the machine placed at their proportionate distances. The lantern contains a candle A, a reflector M N, which is so situated as to have the light, A in its focus. On the fore part of the lantern, there is a thick double convex lens C D, or a plane-convex (usually called a bull's eye,) of short focus. The lantern is closed on every side, so that no light can come out of it, except what passes through the lens C D. In the direction of this lens, there is a tube *x* fig. 57, fixed in the lantern, which has a lateral aperture from side to side; through this the glass slider *aa* with the painted small images, is moved in an inverted position. GH, fig. 58, represents one of these images. The fore part of the tube *x* contains another sliding tube, which carries the double convex lens EF. The effect of those parts is as follows:—The thick lens CD throws a great deal of light from the candle A upon the image GH, and to increase that light still more, the reflector MN is often, but not always, placed in such lanterns; for, as the flame is in the focus of the reflector, the light proceeds in parallel lines from the reflector to the lens CD. The image GH being thus well illuminated sends forth rays from every point, which, by passing through the lens EF are converged to a focus upon the wall, and form the large images as is shewn in fig. 57. In some magic lanterns, instead of the single lens EF, two lenses are used of less curvature, and set at a little distance from each other, and act rather better than a single lens.

200. The Multiplying Glass, is made by grinding down the side of a convex glass into several flat surfaces.

59



Illus. Fig. 59, is the representation of a multiplying glass with the flat sides *h b*, *b d*, *d k*. The object C, seen by the eye at H, will appear multiplied into as many different objects as the glass contains plane surfaces. For since rays flow from the object C to all parts of the glass, and each plane surface will refract these rays to the eye, the same object will appear to the eye in the direction of the rays which enter it through each surface. Thus the rays falling in the direction C *i* H will shew the object in its true place at C, because there they suffer no refraction; but the rays falling upon the surfaces, *h b* and *d k*, will be refracted to *e* and B, and, therefore, to an eye at H, the object C will appear in the direction H *e* E, and H B D, as well as that of H *i* C. The same thing will happen, if, instead of three, there be any number of flat surfaces.

QUESTIONS ON OPTICS.

What is Sir Isaac Newton's theory of light?

What is a *ray* or pencil of light?

What is a *beam* of light, and what a *pencil* of *rays*?

What is a transparent *medium*?

What substances are called *opaque*?

What is the difference between *diverging* and *converging* rays?

What is the *radiant point*?

What is the *focus*?

When is a ray of light said to be *inflected*, when *reflected*, and when *refracted*?

What is said concerning the emission of particles of light in all directions?

What is the rate of velocity with which light moves?

How is it proved that the particles of light (if they are particles,) are extremely small?

What is the rule for estimating the quantity of light emitted by a luminous body?

Give an example of this rule.

Explain the diagram illustrating the *divergency* and *parallelism* of the rays.

What happens when a ray of light passes out of a rarer into a denser medium?

When a ray passes obliquely from a *rarer* to a denser medium, which way in regard to a perpendicular is it refracted?

When a ray passes out of a denser into a *rarer* medium, which way is it refracted?

Illustrate these laws by a sketch.

What is meant by the angle of *incidence*, and what by the angle of reflection?

Describe the various kinds of lenses.

What is the axis of a lens?

If parallel rays fall upon a *plano-convex* lens, what then?

What is meant by *focal distance*?

What is the rule for finding the *focal distance* of a plano-convex lens?

How do you find the focal distance of a *double convex* lens?

What proportion is there between the heat of the focus of a glass and the heat of the sun itself?

What kind of a lens is a common burning-glass?

Explain and illustrate proposition 164.

Explain fig. 46, illustrating proposition 165.

What are the principal phenomena of the rays in connection with the various lenses?

What difference in quantity is there between the angle of *incidence*, and that of *reflection*?

How does Sir Isaac Newton explain the cause of reflection?

What are the chief phenomena of reflected rays?

How many coats are proper to the eye, and what do they enclose?

What are the names of the coats, and how are they situated in respect to each other?

Mention the names of the humours.

Where is the sense of vision situated?

Prove that the images of objects are painted on the retina in an inverted position.

How is it proved that these images are the cause of vision?

What causes dimness of sight in old age?

What is the cause of short-sightedness?

Explain proposition 175.

How do we judge of the distance of an object?

Are all the rays of light *refractible* or *reflexible* alike?

Explain the reason why they are not.

When is light called *homogeneous?* and when *heterogeneous?*

What are the colours produced by homogeneous rays called?

What are those produced by heterogeneous rays called?

How is a ray of light separated into its primary colours?

What are the colours of the spectrum, and in what order do they succeed each other?

What is said of the colours of homogeneous light?

How are the various colours accounted for?

What colour is the colouring matter of various substances, as the leaves of trees, &c.?

What is the cause of the rainbow?

Illustrate by a diagram, how the light is refracted and reflected to produce the rainbow?

What produces the secondary rainbow?

What is the *mirror* or *speculum*?

How do *concave* glasses assist the sight?

How do *convex* glasses assist the sight?

Why do small objects appear larger under the microscope than with the naked eye?

What laws govern the magnifying power of the microscope?

How many kinds of microscopes are there?

Describe each, and the method of using them.

By what rules are the magnifying powers of each of these instruments estimated?

Point out the difference between the *refracting* and *reflecting* telescope.

What is the sole business or effect of telescopes?

Explain why the image of an object is seen through the telescope under an enlarged angle.

Explain and illustrate proposition 193.

How many eye-glasses have telescopes which shew objects in their natural positions?

Explain the difference between the several telescopes described.

What are the dimensions of the several parts of Dr. Herschel's grand telescope?

What is the principle of the *camera obscura?* Describe its operation and use.

What is the *magic* lantern?

Point out the principle of its construction, and describe its effect.

What is the *phantasmagoria?*

Describe the multiplying-glass.

OF ASTRONOMY.

201. Astronomy is the science which teaches the motions of the Earth, the Sun, Moon, Planets, Comets, and Stars, and explains the phenomena occasioned by those motions.

Obs. 1. The student in the day time may observe one of the chief of these motions in the rising, ascent, exaltation, declension, and setting of the sun. In the morning he will see it rise in the eastern part of the heavens, ascend in this hemisphere towards the South, attain its greatest height at noon, and then descend again, till it sets in the West, as far from the South as it rose in the morning. This is the *first* practical lesson in Astronomy.

2. In the night time he may observe the stars rise and set in the East, ascend towards the South, and decline and set to the West; and this will be the *second* lesson.

3. He may, however, observe that one star, viz, that over the North Pole, never moves, and that all the others move around it, and those within a certain distance never set; and, in short, in this *third* lesson, which is worthy of being pursued through successive evenings, he will become master of the general motions of the heavens.

4. He will observe, in a *fourth* lesson, what is also to be pursued through successive nights, that the moon changes its place with regard to the stars, that she increases in light in proportion to her increased distance from the sun, till she arrives at the opposite, or rises as the sun sets; and that the light increases on one side, and decreases on the other, being always towards the sun.

5. He will in like manner observe, that the planets change their motions slowly in regard to the fixed stars, and that both moon and planets move in the same line, or nearly so, among the fixed stars; and this *fifth* lesson may be mixed with others through successive weeks,

5. He will be highly gratified by applying any telescope, (the larger the better, but the smallest will afford much gratification,) to the moon, planets, and stars. He will observe the decrease and increase, and change of the shadows of the Moon's pits; the satellites of Jupiter; the Moon-like appearance of Venus; the ring and moons of Saturn; and many of the constellations and nebulous stars.

7. By mixing such observations on the heavens and heavenly bodies, with the results given in the following paragraphs, of observations made during many thousand years, the student will soon become expert in this most sublime of all the sciences.

202. The *Solar System* consists of the Sun ☉ in the centre:

Of seven *primary planets*, Mercury ☿, Venus ♀, the Earth ⊕, Mars ♂, Jupiter ♃, Saturn ♄, Herschel ♅:

Of four *Asteroids*, or minor planets, Ceres ⚳, Pallas ⚴, Juno ⚵, and Vesta ⚶:

Of eighteen *secondary planets*, the Earth's Moon, Jupiter's four Satellites, Saturn's seven, and six belonging to Herschel:

And of a considerable number of *Comets*.

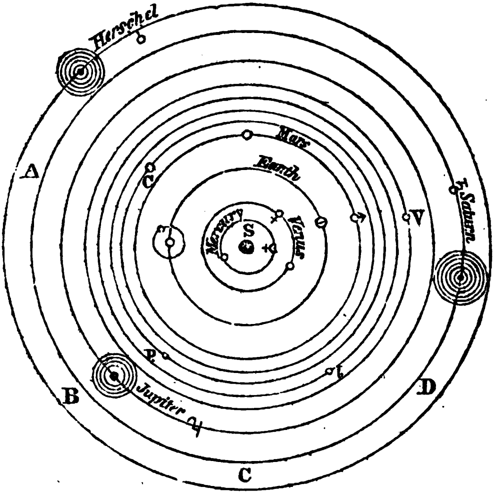
Obs. 1. PTOLEMY supposed the earth to be perfectly at rest, and the sun, moon, planets, comets, and fixed stars, to revolve about it every day; and that, besides this diurnal motion, the sun, moon, planets, and comets, had a motion in respect to the fixed stars, and were situated, in respect to the earth, in the following order: the Moon, Mercury, Venus, the Sun, Mars, Jupiter, Saturn.

2. The system received by the Egyptians was, that the earth was immoveable in the centre, about which revolved, in order, the Moon, Sun, Mars, Jupiter, and Saturn; and about the Sun revolved Mercury and Venus. This disposition will account for the phases of Mercury and Venus, but not for the apparent motions and retrogradations of Mars, Jupiter, Saturn, and Herschel.

3. In the system of Tycho Brahe, a Danish nobleman, the earth is placed immoveable in the centre of the orbits of the sun and moon, without any rotation about its axis; but he made the sun the centre of the orbits of the other planets, which therefore, revolved with the sun about the earth.

4. The system which is now universally received is called *the Copernican*, or *Solar System*. It was taught by Pythagoras, 500 years before Christ; and afterwards rejected, till revived by Copernicus, in the sixteenth century. In this system the Sun is placed in the centre of the system, about which the planets revolve from west to east, in the following order: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and the Herschel planet: beyond which, at immense distances, are placed the fixed stars. The Moon revolves round the earth; and the earth turns about its axis. The other secondary planets move round their respective primaries from west to east, at different distances, and in different periodical times.

5. In the fig. the SOLAR SYSTEM is represented. S is the Sun in the centre, surrounded by circles, representing in succession the orbits of Mercury, Venus, the Earth and Moon, Mars, the four Asteroids; C Ceres, P Pallas, J Juno, V Vesta, Jupiter and his four Moons, Saturn, his ring, and seven moons, and Herschel and his six moons. The student will find it a pleasant exercise to draw the system on larger paper, in which the distances should be in exact proportion.



6. There are several ways of demonstrating that the planets move round the sun; one or two of which shall be mentioned: thus Mercury and Venus always appear in the neighbourhood of the sun, and therefore, if the sun revolved round the earth as a centre, so must those planets; but if they did, then the motion of each would always appear to the inhabitants of the earth nearly equable, and in the same direction; whereas now they are sometimes stationary, or appear to have no proper motion: sometimes they move eastward in reference to the fixed stars, and their motion is then called direct, progressive, or *in consequentia;* sometimes they move westward, or have a retrograde motion, and are then said to move *in antecedentia:* all which appearances are necessary when we admit the sun to be the centre of their orbits and of the earth's, but wholly irreconcilable with any other hypothesis.

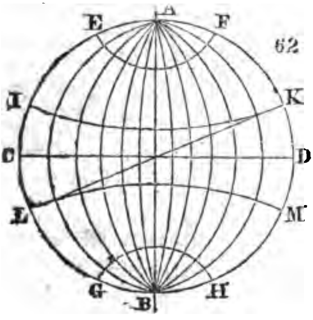
Also, when Mercury and Venus appear in conjunction with the sun, they are sometimes hid behind the body of the sun, and sometimes pass between it and the earth, appearing like a dark spot on the sun's disc or face; but if they have latitude, when in its superior conjunction, that is, when beyond the sun, they shine with a face perfectly circular, like a full moon. But the face disappears in its inferior conjunction, that is, when it is between us and the sun, as the moon does at her change; whence it is evident that their orbits are between the sun and the orbit of the earth. Mars sometimes appears in opposition to the sun, which proves that its orbit includes that of the earth; and that it includes the Sun is plain, otherwise Mars would in its conjunction with the Sun disappear, like Mercury and Venus, which never happens: the same may be observed of Jupiter, Saturn, and Herschel.

7. The motions of the earth in its orbit are proved, by the effect of its motion on the apparent motions of the several planetary bodies. These, as the earth happens to be situated, become stationary, retrograde, or direct, and the variations are exactly measured by motions referred to the earth, like the motions of objects ashore, when we are moving in a boat.

203. The earth is of a globular form, because,

1. The shadow of the earth projected on the moon in an eclipse is always circular.—2. The convexity of the surface of the sea is visible; the mast of an approaching ship being seen before its hull.—3. The north polar star becomes more elevated by travelling northward in proportion to the space passed over.—4. Navigators, by steering their course continually westward, arrive again at the place from whence they departed.

DEFINITIONS RELATING TO THE TERRESTRIAL GLOBE.



62

Obs. The *axis* of the earth is an imaginary line passing through the centre north and south, about which the diurnal revolution is performed. It is represented by the line between A B, fig. 62.

2. The *Poles* of the earth are the extremities of this axis, A B.

3. The *Equator* C D, is an imaginary line passing round the earth east and west, at equal distances from the poles.

4. The small circle E F, is called the *Arctic circle;* the circle G H, is called the *Antarctic circle.*

5. The circle north of the equator I K, is called the *tropic of Cancer*, that south of the equator L M, the *tropic of Capricorn.*

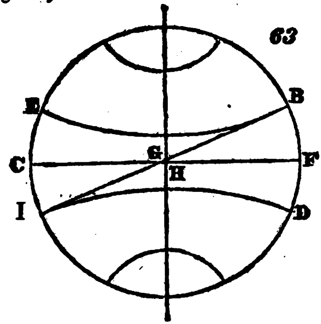
6. The spaces between the ends north and south of the equator are called *zones ;* that space between the tropics is called the *torrid zone;* between the tropics and the polar circles are called the *temperate zones*, and north of the arctic and south of the antarctic circles are called the *frigid zones.*

7. Latitude is distance north or south of the equator ; longitude is distance east or west measured upon the equator, from any assumed point.

Astronomical circles, whether larger or smaller, are divided into 360 degrees ; the length of a degree of course depends upon the magnitude of the circle ; a degree on the earth is about 69 1-2 miles.

DEFINITIONS RELATING TO THE CELESTIAL GLOBE.

Obs. 1. The surface of the Celestial Globe represents the internal surface of the imaginary hollow sphere of the heavens. The lines and figures on the globe are of course imaginary.



2. The line E B, is the *tropic of Cancer.* The line I D, is the tropic of *Capricorn.* The sun never goes north of Cancer nor south of Capricorn.

3. The line C F, is the *Equator* or *Equinoctial line.*

4. The line B I, is the *Ecliptic*, and indicates the path that the sun appears annually to pursue in the heavens. It is divided into 12 equal parts, called signs of the zodiac.

5. The points at which the ecliptic cuts the equator G H, are called the *equinoctial points.*

6. Those two points of the ecliptic farthest from the equator are called *Solstices.*

7. That space in the heavens about 16 degrees in width through the middle of which passes the ecliptic, is called the *zodiac.*

8. The *latitude* of a heavenly body is distance from the ecliptic: *longitude* is distance from the first degree of Aries.

9. The *sensible Horizon* is an imaginary circle, which appears to touch the surface of the earth, and separate the visible part of the heavens from the invisible. The *rational Horizon* is a circle parallel to the former, the plane of which passes through the centre of the earth, and cuts the heavens into two equal hemispheres.

10. The *Poles* of the *Horizon* are two points, the one of which, over the head of the spectator, is called the *Zenith;* the other, which is under his feet, is called the *Nadir*.

11. A circle which passes from north to south through the zenith of any place is called a *Meridian*, and is said to be the meridian of that place. The meridian of any place passing through the poles, and falling perpendicularly upon the horizon, cuts it in two opposite cardinal points, called *North* and *South*.

12. The *Altitude* of any heavenly body above the horizon is the part of a vertical circle intercepted between the body and the horizon, or the angle at the centre of the earth measured by that arc.

13. The *Azimuth* of a heavenly body, is the arc of the horizon intercepted between the meridian and a vertical circle passing through that body; it is eastern or western as the body is east or west of the meridian.

14. The *Amplitude* of a heavenly body at its rising or setting, is the arc of the horizon intercepted between the point where the body rises, and the east or west.

15. The *Declination* of any heavenly body, is its distance from the equator; and is either northern or southern.

16. The *Right Ascension* of any heavenly body is its distance from the first of Aries reckoned upon the equator.

17. A planet's place, as seen from the sun, is called its *Heliocentric* place, and as seen from the earth, its *Geocentric* place.

18. Two planets are said to be in *Conjunction* with each other, when they have the same longitude, or are in the same degree of ecliptic on the same side of the heavens, though their latitude be different. They are said to be in *Opposition* when their longitudes differ half a circle, or they are in opposite sides of the heavens.

19. The celestial sphere is called *right*, *oblique*, or *parallel*, as the equator is at right angles, oblique, or parallel to the horizon.

204. As the earth revolves round its axis daily from west to east, the heavenly bodies appear to a spectator on

the earth to revolve in the same time from east to west, and the alternate succession of day and night is the effect of the revolution of the earth towards and from the sun.

Obs. For all the heavenly bodies appearing to move from east to west, while the earth revolves from west to east, the sun will appear, in each revolution, to rise above the horizon in the east, and after describing a portion of a circle, to set in the west, and will continue below the horizon, till, by the revolution of the earth, it again appears in the east; and thus day and night is alternately produced.

205. As the earth revolves round the sun in 365 days, 6 hours, 56 minutes, 4 seconds, the sun appears to revolve round the earth in the same time, but in the contrary direction.

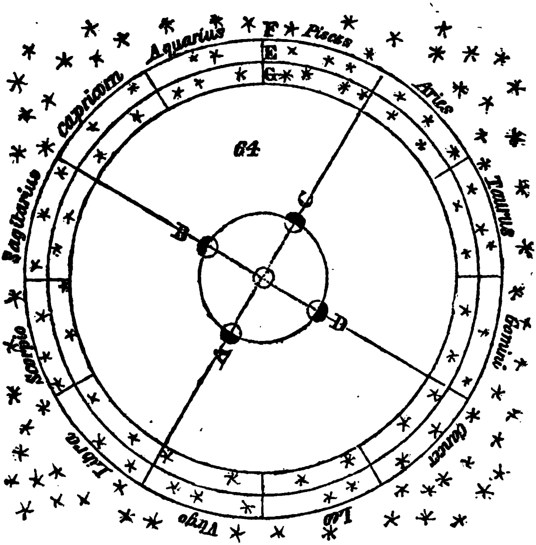
Obs. 1. It is manifest that the circle in which the sun appears to move, is the same in which the earth would appear to move, to a spectator in the sun. Hence the apparent place of the sun being found, the true place of the earth in its orbit is known to be 180° distant.

2. The orbit in which the earth revolves round the sun is not a circle but an ellipse, having the sun in one of its foci.—For the computations of the sun's place, upon this supposition, allowing for the disturbing forces of the planets, are found to agree with observations.

206. The stars round the Zodiac are classed in 12 *Signs:* Aries, Taurus, Gemini, Cancer, Leo, Virgo, Libra, Scorpio, Sagittarius, Capricorn, Aquarius, Pisces.

Obs. 1. The names and characters of the signs are, Aries, ♈ ; Taurus, ♉ ; Gemini, ♊ ; Cancer, ♋ ; Leo, ♌ ; and Virgo, ♍ ; all *northward* of the equator.

Libra, ♎ ; Scorpio, ♏ ; Sagittarius, ♐ ; Capricornus, ♑ ; Aquarius, ♒ ; and Pisces, ♓ ; are *southward* of the equator.



2. The circle E, fig. 64, represents that circle in the heavens in which the sun appears to move, called the *ecliptic.*

3. The circles F G, represent the broad belt or circle in the heavens occupied by the 12 constellations called the *zodiac.*

4. The signs of the zodiac are clusters of stars, and are represented by figures drawn on the celestial globe. They are so situated that the earth in its annual revolution passes directly between them and the sun.

The Sun as he appears to move round in the ecliptic, seems to enter these clusters of stars, and is therefore said to be in this or that sign or constellation. Thus, if a right line, fig. 64, be drawn from the earth passing through the sun till it reaches one of the constellations, the sun is said to be in that constellation in which the line terminates. Thus when the earth is at A, the sun is in the constellation, or sign Aries; when the earth is at B, the sun is in Cancer; when the earth is at C, the sun is in Libra; when the earth is at D, the sun is in Capricorn.

5. The pupil will bear in mind that the observation founded on the idea that the sun and stars revolve round the earth, are founded upon *appearance only* and not upon *facts*. He will therefore not forget while he is imagining that the heavens move around the earth that in fact they are stationary as it respects the earth, and it is the earth that moves round the sun.

207. The axis of the earth in every part of the earth's revolution about the sun, makes with the plane of its orb, that is, of the ecliptic, an angle of 66½ degrees, consequently the planes of the equator and ecliptic, make with each other an angle of 23½ degrees nearly, being the compliment of 90 degrees.

Obs. 1. The obliquity of the ecliptic is not permanent, but is continually diminishing by the ecliptic approaching nearer to a parallelism with the equator, at the rate of about half a second in a year, or from 50″ to 55″ in 100 years.—The inclination at this time is 23° 27′ 46″ nearly. The diminution of the obliquity of the ecliptic to the equator, is owing to the action of the planets upon the earth, especially the planets Venus and Jupiter. The whole diminution, it is said, can never exceed one degree, when it will again increase.

2. The diminution of the obliquity of the ecliptic is a consequence of the approach of the earth's axis towards a perpendicular direction to the plane of the ecliptic; but the earth's axis has, besides the progressive motion, a tremulous one, by which its inclination to the plane of the ecliptic varies backwards and forwards some seconds; the period of these variations is nine years. The tremulous motion is termed the mutation of the earth's axis. Both these motions of the terrestrial axis are occasioned by the action of the sun, moon, and planets, on the earth.

208. The difference of longitude at two places may be found by observing, at the same time from both places, some simultaneous appearance in the heavens.

Obs. If the eclipse of Jupiter's innermost satellite, on the very instant of its immersion into the shadow of Jupiter, be observed by two persons at different places, it will be seen by both at the same instant. But if this instant, with reference to the day, be half an hour, for example, sooner at one place than at the other, because the places differ half an hour in their reckoning of time, their difference of longitude must be 70° 30′; because the whole 360° are equal to 24 hours, and consequently every 15° are equal to an hour.

209. Those who live on opposite sides of the earth, but in the same parallel of latitude, have opposite hours of the day, but the same seasons.

Obs. Being both on the same side of the equator and at the same distance from it, when the sun's declination makes it summer or winter in one of the places, it will be the same at the other; but because they are distant from each other 180° of longitude, when it is noon at one place, it is midnight at the other; these are called *Periœci.*

210. Those who live in opposite parallels of latitude, but under the same meridian, have opposite seasons of the year, but the same hour of the day.

Obs. When the sun has declination towards the north pole, it will be summer to those who live in the northern parallel of latitude, and winter to those who live in the southern parallel of latitude. But having the same longitude, their hours of the day will be the same; these are called *Antœci.*

211. Those who live in opposite parallels of latitude and opposite semicircles of the meridian, have opposite seasons of the year, and opposite hours of the day.

Obs. 1. Because they are in opposite latitudes, they will have opposite seasons; and because they are in opposite semicircles of the meridian, they will have noon when it is midnight at the other place; these are called *Antipodes.*

2. These and many other propositions will be better understood by means of the problems on the Globes and Maps, to be found in *Goldsmith's Grammar*, and his *Royal Atlas*.

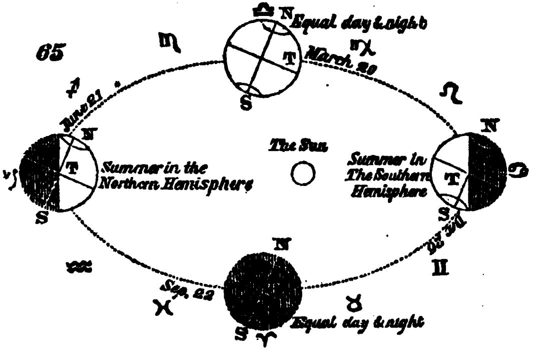
212. The axis of the earth, in its circuit round the sun, being inclined to the plane or level of its orbit, this inclination occasions the succession of the four seasons.

Obs. 1. The earth's axis makes an angle of 66° 32′ with its orbit, that is, with the ecliptic, and always preserves its parallelism, or is directed towards the same point, at an infinite distance, in the heavens; hence during one half of the year the north pole is continually illuminated by the sun, and the south pole is all that time in darkness: and during the other half of the year, the south pole is constantly in the light, and the north pole is in darkness: and other parts in a proportional degree partake of this vicissitude, and create the variety of the seasons.

2. The difference in the degrees of heat, is owing chiefly to the different heights to which the sun rises above the horizon

and the different length of the days. When the sun rises highest in summer its rays fall less obliquely, and consequently, more of them fall on any given portion of the earth's surface than in winter, when the rays fall obliquely; and when the days are long, and the nights short, the earth and air are more heated in the day than they are cooled in the night, and the reverse when the days are short and the nights long.

65



Illus. The lengthening and shortening of the days, and the different seasons, are produced by the motion of the earth T, fig. 65, in its orbit round the sun S. The axis of the earth N S inclines to the plane of the orbit, and is parallel to itself in all parts of the orbit. In June the north pole N inclines to the sun, and it is summer in the northern parts of the earth; in December the north pole declines from the sun, and it is winter in the northern and summer in the southern hemisphere.

213. The orbit in which the earth revolves about the sun, is not a circle but an ellipsis or oval.

Obs. 1. The sun's diameter being on the thirty-first of December 31′ 45″, and on the second of July 32′ 45″, or nearly one thirtieth longer, and consequently so much nearer, and increasing and decreasing gradually, it is evident the orbit of the earth is an ellipsis. Newton found the mean diameter of the sun, to be 32′ 12″, but as above it is 32′ 15″.

2. In January therefore, the earth is in its *perihelion*, and in July in its *aphelion*, and having a smaller circle to traverse in

its perihelion-half than its aphelion-half, it is eight days longer in performing the aphelion-half of its orbit than the perihelion-half.

3. The motion of the aphelion point is 1° 44′ in 100 years; so that it will pass round the ecliptic in 20700 years.

4. In the perihelion, the earth moves in its orbit 61′ 11″ per day, and in the aphelion, but 57′ 10″, being one-fifteenth less. Its mean daily motion is 59′ 10 1-2″.

214. Twilight is occasioned by the atmosphere above the horizon reflecting rays of the sun, when the sun itself is below the horizon.

Obs. 1. When the sun is at any point below the horizon, it cannot be directly seen by a spectator. But, because rays from the sun can pass to the part of the atmosphere above the head of the spectator, this part of the atmosphere will be illuminated before the sun rises, or after it sets, and will become visible by reflection to the spectator; that is, *twilight* will be produced.

2. It is entirely owing to the reflection of atmosphere that the heavens appear bright in the day time. For without it, only that part would be luminous in which the sun is placed; and if we could live without air, and should turn our backs to the sun, the whole heavens would appear as dark as in the night. In this case also we should have no twilight, but a sudden transition from the brightest sunshine to dark night immediately upon the setting of the sun.

3. The *twilight* is longest in a parallel sphere, and shortest in a right sphere: and in an oblique sphere, the nearer the sphere approaches to a parallel, the longer is the twilight, because twilight lasts till the sun is eighteen degrees perpendicularly below the horizon.

215. The atmosphere also refracts the sun's rays in such a manner, as to bring him into sight, every clear day before he rises in the horizon, and to keep him in view for some minutes, after he is really set below it. The effect of this refraction is about six minutes of time, or 33′ of space, being rather more than the diameter of the sun or moon.

Obs. From the same cause, the heavenly bodies appear higher than they really are, so that to bring the apparent altitudes to the true ones, the quantity of refraction must be subtracted. The higher they rise the less are the rays refracted, and when the heavenly bodies are in the zenith, they suffer no refraction.

216. A *Natural day* is the time the sun takes in passing from the meridian of any place, till it comes round to the same meridian again; but the natural days are not equal to one another: and the *Equation* of time, is the difference between the mean length of the natural day (or 24 hours) and the length of any single day measured by the sun's motion, or between *mean time* and *apparent time*.

Obs. 1. For any natural day is the time in which the earth performs one revolution round its axis, and such a portion of a second as is equal to the sun's increments of right ascension for that day; but the sun's daily increments of right ascension are unequal; therefore the additional portion of the second revolution will sometimes be greater and sometimes less, and consequently, the times in which the natural days are completed will be unequal.

2. If the sun were to move uniformly round the equator in the same time in which it appears to describe the ecliptic, its apparent daily motion would be a measure of mean time. For the natural days in that case being liable to no variation, either from the inclination of the sun's orbit, or the irregularity of its motion, must be equal.

OF THE SUN ☉.

217. The sun is a spherical body, situated near the centre of gravity of the system of planets of which our Earth is one; its diameter is 877547 English miles; and it revolves round its axis in 25 days and 10 hours.

Obs. 1. From several phenomena it is concluded that there is an atmosphere which environs the sun, and extends to a considerable distance from it. It seems likely also that its light and heat are created by gaseous combustion. Euler makes the light equal to 6500 candles at a foot distance, while the moon would be as one candle at 7 1-2 feet; Venus at 421 feet; and Jupiter at 1320 feet. Consequently the sun would appear like Jupiter at 130,000 times his present distance.

2. The period of the sun's revolution about its axis has been determined by means of several dark spots of various figures, which may commonly be seen with telescopes; in the same

manner have the periods of the revolution of Mars, Venus, and Jupiter, about their axes, been determined; whence it is inferred that this motion is general, and belongs to all the planets.

3. In the year 1779, there was a spot on the sun, which was large enough to be seen by the naked eye. It was divided into two parts, and must have been 50,000 miles in diameter. Dr. Herschel supposes, that the spots in the sun are mountains on its surface, which he thinks may be more than 300 miles high. He examined the sun with several powers from 90 to 500, and it appeared, that the black spots are the opaque ground or body of the sun; and that the luminous part is an atmosphere, which, being intercepted or broken, gives us a glimpse of the sun itself.

4. He concludes, that the sun has a very extensive atmosphere, which consists of elastic fluids that are more or less lucid and transparent; and of which the lucid ones furnish us with light. This atmosphere, he thinks, is not less than 1843, nor more than 2765 miles in height; and he supposes that the density of the luminous solar clouds need not be greater than that of our aurora borealis, to produce the effects with which we are acquainted.

5. If one of these spots appears upon the eastern limb or edge of the sun's disc, or face, it moves from thence towards the western edge in about 13 1-2 days. Here the spot disappears; and in about 13 1-2 days more, it is seen again upon the eastern edge; and so continues to go round, completing its revolution in 27 days; during one half of which time we see it on the disc of the sun, and during the other half it disappears.

6. The quantity of matter in the sun, is to that in Jupiter nearly as 1100 to 1, and the distance of that planet from the sun, is in the same ratio to the sun's semi-diameter; consequently, the centre of gravity of the sun and Jupiter is nearly in the superfices of the sun.

7. By the same method of calculation, it will be found, that the common centre of gravity of all the planets cannot be more than the length of the solar diameter distant from the centre of the sun.

8. The sun's diameter is equal to 100 diameters of the earth, and therefore its cubic magnitude must exceed that of the earth one million of times: and its mass is 329,620 times that of the earth, therefore, the sun would move but one foot by the action of the earth, while the earth would move 329, 620 feet by the action of the sun.

9. Its similarity to the other globes of the solar system, in

solidity, atmosphere, surface diversified with mountains, and valleys, and rotation on axis, lead us to suppose, that it is most probably inhabited, like the rest of the planets, by beings whose organs are adapted to their peculiar circumstances.

10. Though it may be objected, from the effects produced at the distance of 95,000,000 miles, that every thing must be scorched up at its surface, yet many facts shew that heat is produced by the sun's rays only when they act on a suitable medium; or when radiated and reflected by suitable surfaces. On the tops of mountains of sufficient height, we always find regions of ice and snow; though if the solar rays themselves conveyed all the heat we find on this globe it ought to be the hottest where their course is the least interrupted.

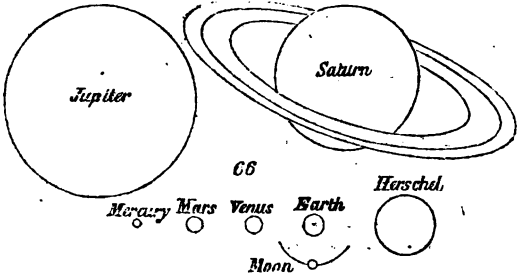
11. If we are to consider all light as analogous, from its equal powers on the eye, it seems likely that the light and heat of the sun are occasioned by the combustion of gas in the upper regions of its atmosphere, not dissimilar perhaps, to the combustion of carburetted hydrogen gas, with which we have lately illuminated our streets and houses. The simultaneous production of light and heat, seems in truth, in all cases to be produced by the combustion of gas.

12. Dr. Herschel conceives the sun and planets to have a general motion at the rate of the earth's motion in its orbit, with relation to the fixed stars; but at this rate, if the distance of the stars is 200,000 times that of the diameter of the earth's orbit, the sun would be 60,000 years in moving over the distance of the nearest fixed star.

OF THE PRIMARY PLANETS.

218. The primary Planets are those which regard the sun as their proper centre. The number already known is seven: Mercury, Venus, the Earth, Mars, Jupiter, Saturn, and Herschel.

Obs. Fig. 66 represents the planets in their true proportions.



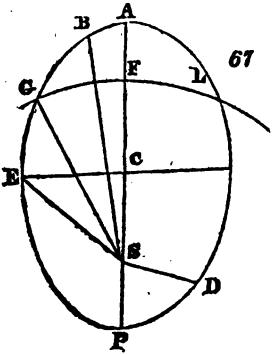
66

219. Four small telescopic planets, called *asteroids* have lately been discovered between the orbits of Mars and Jupiter; called Ceres, Juno, Pallas, and Vesta.

ELEMENTS OF THE PLANETS.

DEFINITIONS.

1. The sun being placed in the focus of the elliptical orbit of a planet, the planet cannot always be at the same distance from the sun; but will be farthest from it when in the extremity A of the greater axis, most distant from the focus S, in which the sun is; and nearest to it when in P.



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The point A is termed the HIGHER APSIS, or the APHELION; and the point P, the LOWER APSIS, or the PERIHELION: these points are constantly varying, and their motion in a century, is called the *secular* motion.

The distance between the centre of the ellipse C, and the sun or focus S, is called EXCENTRICITY.

The greater axis A P, is the LINE of APSIDES.

The straight line S E, drawn from the extremity of the less axis E C to the sun, is the MEAN DISTANCE of the planet from the sun.

The mean distance added to the excentricity is equal to the APHELION DISTANCE.

And the mean distance less by the excentricity is equal to the PERIHELION DISTANCE.

When the sun or moon is at the greatest distance from the earth, it is said to be in its APOGEE; and when at the least distance, in its PERIGEE.

2. A planet does not proceed in its orbit with an equable motion; but in such a manner, that a line drawn from the sun to the planet, describes an *area* always proportionate to the time. For example, suppose a planet to be in A, whence in a certain time it arrives at B; the space or *area* which the line S A, called the RADIUS VECTOR, describes, is the triangle ASB. Supposing the planet to be in P, let the straight line SD be so drawn that the area PSB may be equal to the area ASP; then the planet will move through the arcs AB and PD in equal times, though these arcs are unequal, being nearly to each other reciprocally as their distances from the sun; for the areas being equal, the arc PD is as much in proportion greater than the arc AB, as SP is less than SA.

3. A planet's ANOMALY is its distance from the aphelion. When a planet is supposed to move in a circle in the centre of which is the sun, the portion FG of the circle bears the same ratio to the whole circumference, that the time since the planet passed its aphelion does to the time of its whole revolution, and is termed the MEAN ANOMALY. If the elliptical orbit of a planet, be so divided that the area ASG shall have the same ratio to the whole ellipse ABED, which the time since the planet passed its aphelion, has to its whole period, then is the angle ASG the measure of the planet's distance from the aphelion, at the time the planet is in G; this angle is called the TRUE ANOMALY. The difference between the mean anomaly, and the true anomaly, is called the EQUATION of the *Planet's Centre.*

4. When the motion of a planet is reckoned from the equinoctial point, it is called its LONGITUDE. There are tables of each planet's mean motion, and of the equation of its centre, with its relative distance from the sun, and its latitude in any part of its orbit; whence its true place may be calculated at any time.

5. Let SG be a mean proportion between the semi-axis major CA, and the semi-axis minor CE, then, when the planet comes to the point G or L, the equation of its centre will be the greatest, and this GREATEST EQUATION varies according to the excentricity of the orbit. The points G and L may be found by observation, and as A lies equally between them, the aphelion may from them be determined.

6. A planet's ELONGATION, or its angular distance from the sun, is an angle formed at the earth by two lines, one drawn from the earth to the sun, and one from the earth to the planet.

7. A planet's PERIODIC TIME, or the time it takes in a revolution about the sun, is found by observing when it is in any point of its orbit, and after any number of revolutions, observing when it comes to the same point again: that interval of time divided by the number of revolutions, gives the time of one. This is called a TROPICAL REVOLUTION; but as while the planet is making this revolution, the equinoctial point is moved by the precession of the equinoxes, there will be an additional time required for the planet to move, before it will be with the same star it was with, when the former observation was made, and, therefore, the SIDEREAL REVOLUTION, or that which brings it again to the same star, exceeds the *tropical.*

8. A person situated on the earth, will perceive that a planet will appear to move sometimes in the order of the signs, or DIRECT, and sometimes in a contrary direction, or RETROGRADE, and to be sometimes STATIONARY. An inferior planet's motion is *direct* through its superior conjunction, and *retrograde* through its inferior; between which situations it is *stationary.* A superior planet is *retrograde* when in opposition to the sun, and *direct* when in conjunction with it; and between those situations it is *stationary.*

9. The planes or levels of the planet's orbits are variously inclined to that of the ecliptic. The opposite points in which the plane of an orbit *crosses* the plane of the ecliptic, are called NODES: that at which the planet rises north of the ecliptic, is called the *ascending node*, and the other the *descending node.* The line which joins the nodes, passing through the sun, is called the *line of the nodes.*

OF MERCURY ☿.

220. The diameter of this planet is 3180 miles.

Its sidereal revolution 87d. 23h. 15'. 44".

Longitude, January 1st, 1815,	8s.	23°	25'.	
Annual Motion	1	23	43	3
Aphelion Place	8	14	22	0
Secular motion of aphelion		1	33	45
Ascending node	1	16	4	1
Secular motion of the node		1	12	10
Inclination of orbit		7	0	0
Greatest equation		23	40	0
Excentricity in miles				7,434,424

Relative mean distance from the sun	38710
Mean distance in miles - . -	36,841,468

Obs. 1. The *greatest elongation* of Mercury from the sun being but 28° 20′ it is mostly above the horizon when the sun is; and, therefore, is seldom seen. When it is visible it is in the east just before sun-rise, or in the west soon after sun-set, accordingly as its place follows or precedes that of the sun.

2. When viewed with a telescope, it appears with phases similar to the moon. When in its inferior conjunction, if its latitude be less than the semi-diameter of the sun, it passes over the sun's face; this is called a transit of Mercury.

3. The density of the sun's heat, which is in the same proportion as his light, is seven times as great in Mercury as with us; so that water there, would be carried off in the shape of steam: for by experiments with the thermometer, it appears that a heat 7 times greater than that of the sun's beams in summer, will serve to make water boil. This however depends on the weight of the atmosphere of Mercury.

OF VENUS ♀.

221. The diameter of this planet is 9498 miles.
It revolves round its axis in 23h. 20′.
Sidereal revolution 224d. 16h. 49′ 10″. 6.

Longitude, Jan. 1, 1815 .	9s.	11°.	45′.	
Annual motion	7	14	47	30
Aphelion	10	8	35	18
Secular motion of aphelion .		1	21	0
Ascending node . . .	2	14	57	18
Secular motion of node . .			51	40
Inclination of orbit . . .		3	23	35
Greatest equation . . .			47	20
Relative excentricity . . .				498
Excentricity in miles . .				465387
Relative mean distance from the sun				72333
Mean distance in miles				68,891,486
The greatest elongation, is				47°.48′.

Obs. 1. When the elongation of Venus is 39° 44′ between its inferior conjunction and greatest elongation, it appears brightest; for then, though its phasis is but the 53.200ths of a circle, it is so much nearer to the earth than in its superior conjunction, when it appears with a perfect disc, that the want of surface is more than compensated by the intenseness of the light: in that situation Venus is often seen by the unassisted eye in broad day-light.

2. Like Mercury, it sometimes passes over the sun's face, and its transit has been applied to one of the most important problems in astronomy, as by it, the true distances of the planets from the sun have been determined.

3. When Venus is to the west of the sun, it rises before the sun, and is called a morning star; this appearance continues about 290 days together; when this planet is to the east of the sun, it sets after the sun, and is called an evening star for about the same period, 290 days. Venus appears the brightest of the planets: it has a considerable atmosphere, and some astronomers assert, that they have discovered mountains on its surface.

OF THE EARTH ⊕.

222. The diameter of the earth is 7928 miles.
It revolves round its axis in 23h. 56'. 4".
Sidereal revolution 365d. 6h. 9'. 11". 5.

Longitude, Jan. 1st, 1815,	3s. 10°. 16'. 54".
Aphelion	3 9 39 25
Secular motion of aphelion .	1 43 35
Greatest equation	1 55 36.5
Horizontal Parallax, or angle of its semi-diameter at the sun, . .	8°. 65".
Inclination of axis, Jan. 1815, .	23°. 27'. 46".4
Relative excentricity . .	1681.395
Excentricity in miles . . .	1,571,285
Mean distance from the sun . . .	95,173,127

223. In the daily revolution of the earth round its axis, the *centrifugal* force diminishes the weight of bodies more at the equator than in any other place on the surface of the earth, in the duplicate ratio of the semi-diameter to the cosine of the latitude of the place.

Obs. 1. As the earth revolves upon its axis, every place on its surface, except the two poles, describes a circle, the plane of which is perpendicular to the axis, and the radius of which is the distance of that surface from the axis.

2. Whence a body at the equator has its centrifugal force as much greater than a body between it and the pole, as the radius of the circle of the equator is greater than that radius; and universally, the centrifugal force at the equator, is to the centrifugal force at any other place on the surface of the earth, as the semi-diameter of the earth is to the cosine of the latitude of the place. And since it is manifest, that the gravity must be diminished as much as the centrifugal force is increased, the gravity of a body at the equator, is as much less than that of a body at any other place on the earth, as the semi-diameter of the earth is greater than the cosine of the latitude of the place.

3. It is found by calculation from this prop, that gravity at the equator is diminished by the centrifugal force, in the ratio of 288 to 289, and if the diurnal motion of the earth round its axis was about 17 times faster than it is, the centrifugal force would at the equator, be equal to the power of gravity, and all bodies there would entirely lose their weight. But if the earth revolved still quicker than this, they would all fly off.

4. Since a place in the equator describes a circle of 24,930 miles in 24 hours, it is evident that the velocity with which that place moves, is at the rate of 17.3 miles per minute. The velocity in any parallel of latitude decreases in the proportion of the cosine of latitude to the radius. Thus, for the latitude of London, say, as rad.: cos. 51°. 30′. :: velocity of the equator; velocity of London; by logarithms, as 10.00000: 9.794150 :: 1.232046 : 1.026196=10.6 miles; that is, London moves about the axis of the earth at the rate of more than 10 1-2 miles in a minute of time.

5. Lagrange calculates that the obliquity of the ecliptic has diminished 2000 years, and will diminish 2000 more, and Schubert determines its limits at 20° 34′ and 27° 48′. Its variation in a century is 50″. On January 1, 1815, it was 23° 27′ 46″ 4.

224. The earth is an oblate spheroid, elevated at the equator and depressed at the poles.

Obs. 1. It has been found by observation, that a pendulum, shorter by 2.169 lines, is required to vibrate seconds at the equator than at the poles; but the length of pendulums vibrating in the same time are as the gravities of the places where they vibrate; therefore the gravity at the poles is greater than at the equator. And it has been found by Sir I. Newton, that this difference of gravity is so much greater than would arise from the centrifugal force alone, that the ratio of the equatorial diameter of the earth to the polar diameter, must be as 230 to 229, which makes the equatorial diameter exceed the polar by about 34 miles.

2. Hence bodies near the poles are heavier than the same bodies towards the equator; (1) Because they are nearer the earth's centre, where the whole force of the earth's attraction is accumulated; (2) Because their centrifugal force is less on account of their diurnal motion being slower. For both these reasons, bodies carried from the poles towards the equator, gradually lose their weight.

3. And the degrees of latitude upon the earth's surface are longer at the poles than at the equator. For an arc of a meridian near the poles is less curved than near the equator; that is, it is an arc of a larger circle: whence a degree measured upon that arc, must be greater than upon an arc of the same meridian at the equator.

225. The equinoctial points move *in antecedentia*, or go backwards from east to west, contrary to the order of the signs. This motion is called the *precession of the equinoxes*, because it carries the equinoctial points forward in regard to the signs. And the *precession of the equinoxes* make the tropical year shorter than the periodical year.

Obs. If, while the sun moves in the order of the signs, the equinoctial point moves in the contrary direction, it is manifest, that the sun must arrive at the solstitial or equinoctial point from which it set out, before it arrives at the same place in the zodiac, or must complete the tropical year sooner than the periodical year. The tropical year is observed to be 365 days, 5 hours, 49 minutes; the periodical year, 365 days, 6 hours, 4 minutes, 56 seconds.

226. The precession of the equinoxes is caused by the action of the sun and moon on that excess of matter about the equatorial parts of the earth, by which, from a perfect sphere it becomes an oblate spheroid.

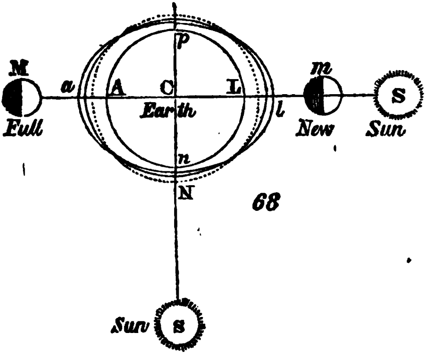
Obs. 1. If the excess of matter at the equator be considered as a ring encompassing the earth at any distance, as Saturn is encompassed by its ring; if it be supposed that this ring moves round its centre, the same way in which the moon move round the earth; it is obvious that every point of this ring will be acted upon by the disturbing force of the sun in the same manner as the moon is acted upon. Particularly, the motion of the nodes of this ring, and consequently, of the whole ring which moves with these nodes, and its inclination to the plane in which its centre moves will be affected in the same manner with the orbit of the moon: whence, its nodes when in syzygies will stand still, and its inclination will be greatest; but in all other situations, the nodes will go backwards, and fastest of all when in the quadratures, at which time the inclination of the ring will be the least. This will be the case whatever be the thickness of the ring, or its distance from the centre. If this ring be supposed to adhere to the earth, it is obvious that it will still have the motions described above, and that, in this situation, the earth itself must participate of these motions.

2. Hence the axis of the earth, being perpendicular to the plane of the equator, changes there with its inclination to the plane of the ecliptic twice in every revolution of the earth about the sun. For instance, it increases whilst the earth is moving from the solstitial to the equinoctial, and diminishes as much in its passage from the equinoctial to the solstitial points: which phenomenon is called the nutation of the poles.

3. This precession of the equinoxes is found to be 50 seconds of a degree every year, westward or contrary to the sun's annual motion: so that with respect to the fixed stars, the equinoctial points fall backwards 30 degrees, in 2160 years, whence the stars will appear to have gone 20 degrees forward, with respect to the signs of the ecliptic, which are reckoned from the equinoctial point. Thus, the stars which were formerly in Aries, are now in Taurus, &c. This period is completed in 25,920 years.

4. The student should be aware that the precession of the equinoxes which merely changes the position of the stars with reference to the nodes on the earth's orbit, is different from the progression of the line of Apsides, or of the Aphelion or Perihelion points at the rate of 1° 44′ in a century, or round the ecliptic in 20700 years. Sir Richard Phillips, deduces from this motion, and from the varied action of the Sun in both hemispheres, a theory, by which he accounts for the present aggregation of water in the southern hemisphere, and concludes, that the same aggregation will take place in the northern hemisphere, when the Perihelion has its utmost northern declination.

227. There are two TIDES every twenty-four hours, and they are caused by the attraction of the moon and of the sun.



68

1. Let A*p*L*n* fig. 68, be the earth, and C its centre; let the dotted circle PN represent a mass of water covering the surface of the earth; let M, *m*, be the moon: S, *s*, the sun in different situations. Because the power of gravity diminishes as the squares of the distances increase, the waters on the side of the earth A are more attracted by the moon at M, than the central parts of the earth C, and the central parts are more attracted than the waters on the opposite side of the earth at L; consequently, the waters on the side L will be attracted less than the centre, or will recede from thence. Therefore, while the moon is at M, the waters will rise towards *a* and *l* on the opposite sides of the earth A,L; while, by the oblique attraction of the moon, the waters at P and N will be depressed.

2. Or thus; because the moon and earth are continually revolving about their common centre of gravity, suppose *a*; the points A, C, L, describing circles about this common centre in the same periodical times, the forces acquired to retain them in these circles, will be to each other as their distances from the centre *a*A,*a*C,*a*L. Consequently, the point L requires a greater force than C, and C than A, to retain it in its orbit. Now these points are retained in their respective circles by the moon at M; and, consequently, the point L, which is most remote, and therefore requires the greatest force, is attracted the least, whilst A, the nearest point, is attracted the most. Thus, the water about A being attracted too much, and that about L too little, both will have their gravity diminished by the action of the moon, and will endeavour to leave the centre C; while

the water at P and N, having their gravity increased by the same cause, will subside. Hence the form of the water on the surface of the earth will become an oblong spheroid.

3. This oval of waters keeps pace with the moon in its monthly course round the earth; while the earth, by its daily rotation about its axis, presents each part of its surface to the direct action of the moon, twice each day, and thus produces two floods and two ebbs. But because the moon is in the mean time passing from east to west in its orbit, it comes to the meridian of any place later than it did the preceding day; whence the two floods and ebbs require nearly 25 hours to complete them. The tide is at the greatest height, not when the moon is in the meridian, but some time afterwards, because the force by which the moon raises the tide continues to act for some time after it has passed the meridian.

4. As the moon thus raises the water in one place, and depresses it in another, the sun does the same; but in a much less degree, on account of the small ratio of the semi-diameter of the earth to the distance of the sun; for, as it was shewn of the moon, that the force of the sun by which it disturbs its motion is as the distance of the moon from the earth to that of the sun from the same, so, in this case, the force of the sun to disturb the waters is as the semi-diameter of the earth to the distance of the sun, which ratio is very small.

228. The tides are greatest at the new and full moons, and least at the first and last quadratures, and the highest tides are near the time of the equinoxes.

When the moon is in conjunction or opposition with the sun, as M, *m*, S, the tides which each endeavours to raise are in the same place; whereas, when the moon is in the first or last quarter, the sun being in the meridian when the moon is in the horizon, as M, Q, depresses the water where the moon raises it; whence the tides are then the least of all. On the full and new moons, which happens about the equinoxes, when the luminaries are both in the equator or near it, the tides are the greatest of all: for first, the two eminences of water are at the greatest distance from the poles, and hence the difference between ebb and flood is more sensible; for if those eminences were at the poles, it is obvious we should not perceive any tide at all; secondly, the equatorial diameter of the earth produced passes through the moon, which diameter is longer than any other, and consequently, there is greater disproportion between the distances of the zenith, centre, and nadir, from the centre of

gravity of the earth and moon, in this situation, than in any other: and thirdly, the water rising higher in the open seas, rushes to the shores with greater force, where being stopped, it rises higher still; for it not only rises at the shores in proportion to the height it rises to the open seas, but also according to the velocity with which it flows from thence against the shore. The spring tides which happen a little before the vernal and after the autumnal equinox, are the greatest of all, because the sun is nearer the earth in winter than in the summer.

229. When the moon is in the northern hemisphere, it produces a greater tide while it is in the meridian above the horizon, than when it is in the meridian below it; when in the southern hemisphere, the reverse.

Obs. **For the like reason, when the moon is in the southern signs, the greatest tides on the other side of the equator will be when it is below our horizon, and the least tides when it is above it.**

2. What hath been said of the tides, must be understood upon supposition, that the globe of the earth is entirely covered with water to a considerable depth; but continents which stop the tide, streights between them, islands, and the shallowness of the sea in some places, which are all impediments to the course of the water, cause many exceptions which can only be explained from particular observations on the nature of tides at different places.

OF MARS ♂.

230. The diameter of Mars is 5400 miles.—It revolves about its axis in 24h. 40′.

Sidereal revolution	686d. 23h. 30′. 35″ 6. or 1 year, 321 days.			
Longitude, Jan. 1, 1815 . .	7s.	28°	1′	
Annual motion . . .	6	11	17	10
Aphelion	5	2	35	14
Secular motion of aphelion .		1	51	40
Node	1	18	6	38
Secular motion of node . .			46	40
Inclination of orbit . . .			1	51
Greatest equation . . .		10	40	40
Relative excentricity . .	14183.7			

Excentricity in miles - -	13,254,852
Relative mean distance from the sun	152,369.27
Mean distance in miles - -	145,014,148

Obs. 1. When Mars is in opposition to the sun, it is nearest to the earth, and its diameter consequently appears the greatest. It never shines with a bright light, but has a red appearance, whence it is concluded it has a dense atmosphere. It appears with different phases according to its position, though never horned, its face being always greater than a semi-circle.

The following particulars respecting Mars are given by Dr. Herschel, after long and accurate observations.

The axis of Mars is inclined to the ecliptic 59° 42′.

The node of the axis is in 17° 47′ of Pisces.

The obliquity of the ecliptic on the globe of Mars, is 28° 42′.

The point Aries on the martial ecliptic answers to our 19° 28′ of Sagittarius.

The figure of Mars is that of an oblate spheroid, whose equatorial diameter is to the polar one as 1355 to 1272, or as 16 to 15 nearly.

The equatorial diameter of Mars, reduced to the mean distance of the earth from the sun, 9″ 8‴.

And that planet has a considerable, but moderate atmosphere, so that its inhabitants, probably, enjoy a situation, in many respects, similar to ours.

Of Vesta ⚶.

231. Diameter 1800 miles.

Distance from the sun -	224,145,000.
Sidereal revolution - -	4 years, 4 months.
Inclination of orbit - -	16°
Excentricity in miles - -	30,000,000
Ascending node - -	5s. 11° 6′

Of Juno or Harding ⚵.

Diameter 1500 miles.

Distance from the sun - -	253,541,000
Sidereal revolution - - -	5 years.
Inclination of orbits - - -	21°
Excentricity in miles - - -	60,000,000

OF CERES OR PIAZZA ⚳.

233. Diameter 1700 miles.

Sidereal revolution 1680 days, or 4 years 266 days.

Distance from the sun	263,344,042		
Excentricity	21700		
Inclination of orbit		10°	36′
Ascending node	25	21	6
Longitude, Jan. 1, 1801	25	17	19
Aphelion	10s	26	9

OF PALLAS OR OLBERS ⚴.

234. Diameter 2000.

Sidereal revolution { 1682 days, or 4 years, 7 months, and 11 days.

Distance from the sun	263,153,691.		
Excentricity	24640		
Inclination		34°	39′
Ascending node	5s.	22	28
Longitude, Jan. 1, 1804	9	29	53
Aphelion	10	1	7
Annual motion	2	18	11

Obs. These anomalous bodies, so unlike the other primary planets, Dr. Herschel has denominated Asteroids. Probably they are the fragments of some comet; or perhaps other similar bodies abound in the solar system, though they have hitherto from their smallness or darkness, escaped observation.

OF JUPITER ♃.

235. Diameter 94000 miles.

Diurnal rotation 9h. 56′.

Sidereal revolution 4332d.14h.27′ 10.8,or 11y.315d.

Geo. longitude, Jan. 1, 1815	6s.	9°.	20′.	
Annual motion	0	0	20	34
Aphelion	6	11	17	48
Secular motion of Aphelion		1	34	33
Node	3	8	31	14
Secular motion of node			59	30
Inclination of orbit		1	18	56

Greatest equation	5 31
Relative excentricity	25013.3
Excentricity in miles	23375454
Mean distance in miles	495,990,976

Obs. 1. Jupiter is the largest of the planets, and has a bright appearance; but less so than Venus, on account of its much greater distance. Like Mars, it appears largest when in opposition to the sun; when it is to the west of the sun, it is a morning star, and when to the east of it an evening star. Its axis being nearly perpendicular to the plane of the orbit, there is but little diversity of seasons. It is surrounded by many faint substances, called belts, which are parallel to its equator; their numbers are variable; between them are frequently seen dark spots. Jupiter has four satellites.

2. Jupiter is surrounded by cloudy substances, subject to frequent changes in their situation and appearance, called his Belts. The Belts are sometimes of a regular form; sometimes interrupted and broken; and sometimes not at all to be seen.

OF SATURN ♄.

236. Saturn's diameter is 78000 miles.

Diurnal rotation 10h. 16′.

Sidereal revolution { 10759d. 1h. 51. 11. 2 or 29y. 162d.

Geo. longitude, Jan. 1, 1815	10s.	0°.	32′.	
Annual motion		12	13	19
Aphelion	8	29	15	11
Secular motion of aphelion		1	50	7
Node	3	22	5	40
Secular motion of node			55	30
Inclination of orbit		2	29	50
Greatest equation		6	26	42
Relative excentricity		53640.42		
Excentricity in miles		50127670		
Mean distance in miles		907,956,130.		

237. Saturn is a beautiful object for a good telescope, having SEVEN MOONS, A DOUBLE RING, and substances similar to the belts of Jupiter. Saturn's ring is a thin, broad, opaque circle, encompassing the planet without touching it; and is very similar to the horizon of a globe surrounding the globe: and as Saturn's axis is perpe

dicular to its ring, if the globe be rectified for the pole, it will aptly represent the planet and the ring.

Obs. 1. The distance of the inner ring from Saturn is 43807 miles, and its breadth 19024 miles: between the two rings is a space of 2927 miles; and the breadth of the outer ring is 7317 miles. Saturn has an atmosphere extending to the ring. The light of this planet is pale and feeble, on account of its great distance.

2. The latter discoveries of Dr. Herschel have shewn, that what was supposed to be a single broad flat ring of Saturn is divided into two parts, lying exactly in the same plane, and revolving about an axis perpendicular to that plane, in 10h. 32′ 15″.

OF HERSCHEL ♅.

238. The diameter of this planet is 35109 miles.

Sidereal revolution 30737d. or 83y. 321d.

Geo. longitude, Jan. 1, 1815. -	8s. 4° 53′
Annual motion - - - - -	0 0 41 30.7
Aphelion - - - - -	11 16 38 51
Secular motion of Aphelion - -	1 28
Ascending node - - - -	2 12 53
Secular motion of node - -	0 26 10
Inclination of orbit - - - -	0 46 20
Greatest equation - - - -	5 27 16
Relative excentricity - -	90,804
Excentricity in miles - -	84,867,518
Relative mean distance from the sun	1,920,330
Mean distance in miles - -	1,816,074,574.

Obs. 1. This planet was discovered by Dr. Herschel, on March 13, 1781. Its appearance is like that of a star of between the sixth and seventh magnitude, and therefore can scarcely be seen without a telescope. The Herschel has six satellites. He modestly called it *Georgium Sidus.*

2. If the planets Mercury, Venus, the Earth, Mars, Jupiter, and Saturn, be in conjunction at any time; in the period of 280,000 years they will be very nearly in conjunction again:

	Revolutions.		*Seconds.*
Mercury after making -	1162577	in	8836185098921
Venus - - - - -	455122	—	8835595689448
The Earth - - - -	280000	—	8835940680000
Mars - - - - -	148878	—	8835946519500

	Revolutions.	*Seconds.*
Jupiter - - - - -	23616 in	8835946544448
Saturn - - - - -	9516 --	8835946558608

3. An easy distinction between a planet and a fixed star is this: the former shines with a steady light, but the latter is constantly twinkling. This twinkling or scintillation of a star is occasioned by the irregular progress of the light from such distant bodies to the eye.

OF THE SECONDARY PLANETS.

239. The secondary planets are those which move round some primary planet, as their centre, in the same manner as the primary planets move round the sun.

The earth is thus attended by one secondary planet, called the Moon; Jupiter by four, Saturn by seven, and Herschel by six.

240. The motion of a secondary planet in its orbit is not nearly so uniform as that of a primary; because though every secondary gravitates chiefly towards its primary as a centre, yet its motion is much disturbed by the unequal action or influence of the sun.

OF THE MOON ●.

241. Its diameter is 2180 miles.

It revolves about its axis in 29d. 12h. 44′.2″. 8283.

Mean distance from the earth .	236347 miles.
Mean excentricity . .	13035′
Greatest equation . .	6°. 18′. 32″.
Greatest inclination of orbit .	5 18
Least inclination of orbit .	5 0
Greatest diameter . .	33 24
Least diameter . .	29 22
Tropical revolution .	27d. 7h. 43′. 4″.6795
Sidereal revolution .	27 7 43 11 5259
Synodic revolution . .	29 12 44 2 .8283
The excentricity .	13,700 miles.
Horizontal parallax .	53′ 46″ to 61′ 26″.
Sidereal revolution of the apogee . . .	8y.312 11 11 39.4049

Sidereal revolution of the node - -	18y.223 7 13 17.744
Longitude, Jan. 1, 1815	5s. 26°. 13′. 53″
Diurnal motion, in respect to the equinox - -	13 10 35.0278

New moon January, 1815, at 10d. 1h. 57′.

Def. 1. The *tropical revolution* signifies the complete revolution of 12 signs, performed round the earth, and is sometimes called a periodical month.

The *sidereal* signifies a completion of the motion to the same star, and is something longer than the tropical on account of the precession of the equinoxes.

The *synodic* revolution is the time from one conjunction with the sun, or one new moon to another, this exceeds the sidereal, and it will be found that in 29d. 12h. 44′.2″.8283 that the moon will be again in conjunction with the sun, the earth being at the distance of 29°. 6′ 20′.2 from the place of the former conjunction.

2. When the moon is at its greatest distance from the earth in its orbit, which is ecliptical, or at its higher apsis, it is said to be in its *Apogee;* when at its least distance, or lower apsis in its *Perigee.*

3. When the moon is in conjunction with the sun, it is *New Moon;* when in opposition, it is *Full Moon:* its conjunction and opposition are called by the common name of its *Sysygies.*

242. The moon at its conjunction, is invisible; at its opposition, its whole disc is enlightened; at its quadratures, it is half enlightened; between the conjunction and quadrature, it is horned; and between the quadrature and opposition, it is gibbous.

(*See Fig.* 69—*Frontispiece.*)

Illus. S is the sun, T the earth, ABC, &c. the moon in its orbit. One half of the moon is always enlightened by the sun. At A, the moon is between the earth and sun, it is then *new;* and is invisible as represented at *a:* at B the enlightened part *x s* is turned to the earth, and she appears horned as at *b;* at C the half of the enlightened side is turned to the earth, and she appears a half moon as at *c;* at D the part *x s* is turned to the earth, and it appears as at *d;* and at E the whole of the enlightened part of the moon is turned to the earth, and we have full moon as at *e.* As she passes through the rest of the orbit, she puts on the same phases as before, but in a contrary order.

Obs. The earth must be a satellite to the moon, and subject to the same changes, but more than 13 times larger than the moon appears to us. At new moon to us, the earth appears full to her.

243. The moon always has nearly the same side towards the earth.

Obs. 1. Hence if the moon revolves about its axis, its periodical time must be equal to that of its revolution in its orbit round the earth. This is also found to be the case with the fifth satellite of Saturn as it regards the primary.

2. Though the year is of the same absolute length, both to the earth and moon, yet the number of days in each is very different; the former having 365 1-4 natural days, but the latter only about 12 7-19, every day and night in the moon being as long as 29 1-2 on the earth.

244. The moon appears to have two librations, one upon a line perpendicular to its axis, called its libration in latitude; the other upon its axis, called its libration in longitude.

Obs. This appears from observation; some small portions of the surface of the moon being visible in some parts, and invisible in other parts, of its orbit; that is, in consequence of her libration in latitude we sometimes see one pole and sometimes the other. And by this libration in longitude, more of the western limb is sometimes seen, and at others more of the eastern. The inclination of her axis to her orbit is 60° 49′.

245. The nearer the moon is to its *syzygies*,* the greater is its velocity; and the nearer it is to its quadratures, the slower it moves.

246. When the earth is in its perihelion, the periodical time of the moon is the greatest; when the earth is in its aphelion, the periodical time of the moon is the least.

Obs. Since all the irregularities of the moon's motion proceed from the action of the sun, it follows, that where the action of the sun is greatest, the irregularities arising from it will be greatest too. But the nearer the earth is to the sun, the greater will be the action of the sun upon the moon; and the more the moon tends towards the sun, the less will it tend towards the earth. When, therefore, the earth is at the perihelion, and consequently at its least distance from the sun, the action of the sun upon the moon will be greatest, and destroy more of its tendency towards the earth than at any other distance. Therefore, when the earth is at the perihelion, the moon will describe a larger orbit about the earth, than when the earth is at any other distance from the sun, and, consequently, her periodical time will then be the longest. But the earth is at its perihelion in the winter, and consequently, then the moon will describe the outermost circle about the earth, and her periodical time will be the longest; which agrees with observation. For the same reason, when the earth is at its aphelion, the tendency of the moon towards the earth will be the greatest, and, consequently, her periodical time the least. And in this case, which will be in the summer, it will describe the innermost circle about the earth.

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* The line joining the centres of the sun, earth, and moon, at the new and full moon, is called the line of syzygies.

247. The excentricity of the moon's orbit is varied in every revolution of the moon, and is greatest when the moon is in syzygy, and least when it is in quadrature: and the orbit is most of all excentrical when the line of the *apsis* is in the syzygies, and least of all excentrical when this line is in the quadratures.

Obs. 1. And if we compare several revolutions of the moon together, we shall find, that when the line of the *apsis* is in the syzygies, the excentricity will be the greatest of all, because in that situation, the difference between the tendency which the moon has to the earth in one of the *apsis*, and that which it has in the opposite one, is the greatest of all; whereas, when the line of the *apsis* is in the quadrature, this difference is the least, and therefore the lunar excentricity will be so too.

When the gravity of the moon towards the earth decreases too fast, the excentricity of her orbit will increase, and when her gravity towards the earth increases too fast, the excentricity of her orbit will decrease: and the orbit itself will approach nearer to a circle.

3. All the irregularities of the moon are greater when the earth is in its perihelion, than when it is in its aphelion, because the effect of the sun's action, whereby they are produced, is inversely as the square of its distance from the earth. They are also greater when the moon is in conjunction with the sun, than in opposition, for the same reason; for the earth and moon, taken together, are nearer the sun in the former situation of the moon, than they are in the latter.

248. The moon is a dark, opaque globe, and its surface is irregular.

Obs. 1. The face of the moon, as seen through a telescope, appears diversified with hills and valleys. This is proved by viewing her at any other time than when she is full; for then there is no regular line bounding light and darkness; but the edge or border of the moon appears jagged; and even in the dark part near the borders of the lucid surface there are seen some small spaces enlightened by the sun's beams. Besides, it is moreover evident, that the spots in the moon taken for mountains and valleys, are really such from their shadows. For in all situations of the moon, the elevated parts are constantly found to cast a triangular shadow in a direction from the sun, and the cavities are always dark on the side next to the sun, and illuminated on the opposite side.

2. By the observations made by Dr. Herschel in November, 1779, and the four following months, we learn, that the altitude of the lunar mountains has been very much exaggerated. His observations were made with great caution, by means of a Newtonian reflector, 6 feet 8 inches long, and with a magnifying power of 222 times, determined by experiment; and the method which he made use of to ascertain the altitude of those mountains, which during that time, he had an opportunity of examining, seems liable to no objection. The rock situated near *Lacus niger,* was found to be about one mile in height, but none of the other mountains, which he measured, proved to be more than half of that altitude; and Dr. Herschel concludes that, with a very few exceptions, the generality of the lunar mountains do not exceed half a mile in their perpendicular elevation.

3. To Dr. Herschel we are also indebted for an account of several burning volcanoes, which he saw at different times in the moon. In the 77th vol. of the Phil. Trans. he says, "I perceive three volcanoes in different places of the dark part of the new moon. Two of them are nearly extinct; or, otherwise in a state of going to break out. The third showed an actual eruption of fire, or of luminous matter." On the next night, Dr. Herschel saw the volcano burn with greater violence than on the preceding evening. He considered the eruption as resembling a small piece of burning charcoal when it is covered by a thin coat of white ashes, which frequently adheres to it, when it has been some time ignited, and it had a degree of brightness, about as strong as that with which such a coal would be seen to glow in faint day-light,

moon, or when the moon, at its conjunction, is in or near one of its nodes.

Obs. For unless the moon is in or near one of its nodes, it cannot appear in or near the same plane with the sun: without which, it cannot appear to us to pass over the disc of the sun. At every other part of its orbit, it will have so much northern or southern latitude, as to appear either above or below the sun. If the moon be *in* one of its nodes having no altitude, it will cover the whole disc of the sun, and produce a *total eclipse*, except when its apparent diameter is less than that of the sun: if it be *near* one of its nodes, having a small degree of latitude, it will only pass over a part of the sun's disc, or the eclipse will be partial.

253. In a total eclipse of the sun, the shadow of the moon falls upon that part of the earth where the eclipse is seen.

Obs. A spectator, placed any where in the centre, will not see any part of the sun, because the moon will intercept all the rays of light which come to him directly from the sun; and it is manifest that, in this situation, the moon, being an opaque body, will cast its shadow upon that part of the earth where the eclipse is total.

254. In a partial eclipse of the sun, a *penumbra*, or imperfect shadow of the moon, falls upon that part of the earth where the partial eclipse is seen.

255. If the moon, when new, is in one of its nodes, the eclipse of the sun will be central.

Obs. 1. For then the centres of the earth, sun, and moon, being all in the plane of the ecliptic, the centre of the moon will pass between the sun's centre and that of the earth.

2. The penumbra of the moon, in a central eclipse, will not cover the whole disc of the earth. The semi-diameter of the moon's penumbra, being equal to the sum of the apparent semi-diameters of the sun and moon, that is, about 16′. 23″. X 15′. 37″. or 32′. at the medium; its diameter is about 64′. whereas the diameter of the earth's disc is about 120′. whence the penumbra cannot cover the whole disc.

3. The height of the shadow of the moon is about 60 1-2 semi-diameters of the earth. The semi-angles of the earth's shadow and the moon's shadow, being each equal to the sun's apparent semi-diameter, the angles are equal to one another, and these cones are similar. Therefore as the semi-diameter of the base of the earth's shadow (that is, of the earth) is to the semi-

diameter of the base of the moon's shadow, (that is, of the moon,) so is the height of the earth's shadow to the height of the moon's shadow. Now the semi-diameter of the earth is to that of the moon nearly as 100 to 28, and the height of the earth's shadow is about 217 semi-diameters of the earth; whence the height of the moon's shadow is equal to about 60 1-2 semi-diameters of the earth; for 100 : 28 :: 217 60 1-4 nearly.

256. An eclipse of the sun is said to be *annular*, when at the time of the eclipse a ring of the sun appears round the edges of the moon; and a central eclipse of the sun will be an annular one, if the distance of the moon from the earth at the time of the eclipse be greater than its mean distance.

257. If the orbit of the earth and that of the moon were both in the same plane, there would be an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon. But the orbit of the moon makes an angle of about five degrees and a quarter, with the plane of the orbit of the earth, and crosses it in two points called nodes.

Obs. 1. Astronomers have calculated that, if the moon be less than 17° 21′ from either node, at the time of new moon, the sun may be eclipsed; or if less than 11° 34′ from either node, at the full moon, the moon may be eclipsed; at all other times there can be no eclipse, for the shadow of the moon will fall either above or below the earth at the time of new moon; and the shadow of the earth will fall either above or below the moon, at the time of full moon.

2. To illustrate this, suppose the right hand part of the moon's orbit, fig. 70, to be elevated above the plane of the paper or earth's orbit, it is evident that the earth's shadow, at full moon, would fall below the moon; the left hand part of the moon's orbit at the same time would be depressed below the plane of the paper, and the shadow of the moon, at the time of new moon, would fall below the earth. In this case, the moon's nodes would be between E and *a*, and between G and *b*, and there would be no eclipse, either at the full or new moon; but, if the part of the moon's orbit between G and *b* be elevated above the plane of the paper, or earth's orbit, the part between E and *a* will be depressed, the line of the moon's

nodes will then pass through the centre of the earth and that of the moon, and an eclipse will ensue.

3. An eclipse of the sun begins on the western side of his disc, and ends on the eastern; and an eclipse of the moon begins on the eastern side of her disc, and ends on the western.

4. The average number of eclipses in a year is *four*, two of the sun, and two of the moon; and, as the sun and moon are as long below the horizon of any *particular place* as they are above it, the average number of visible eclipses in a year is two, one of the sun and one of the moon. *Keith.*

258. When the moon is near the first of Aries, and is moving towards the tropic of Cancer, the time of its rising will vary but little for several days together, and produce the phenomena of *a Harvest moon*.

Obs. 1. If the moon were to move in the equator, its motion in its orbit, by which it describes a revolution, in respect of the sun, 29 days, 12 hours, would carry it every day eastward from the sun about 22° 11′, whence, its time of rising would vary daily about 50 minutes. But because the moon's orbit is oblique to the equator, nearly coinciding with the ecliptic, different parts of it make different angles with the horizon, as they rise or set; those parts which rise with the smallest angles, setting with the greatest, and the reverse. Now the less this angle is, the greater portion of the orbit rises in the same time. Consequently, when the moon is in those parts which rise or set with the smallest angles, it rises or sets with the least difference of time, and the reverse. But in northern latitudes, the smallest angle of the ecliptic and horizon is made when Aries rises and Libra sets, and the greatest when Libra rises and Aries sets; and therefore, when the moon rises in Aries, it rises with the least difference of time. Now the moon is in conjunction in or near Aries, when the sun is in or near Libra, that is in the autumnal months; when the moon rises in Aries, whilst the sun is setting in Libra, the time of its rising is observed to vary only two hours in 6 days in the latitude of London. This is called the HARVEST MOON.

2. This circumstance takes place every month; but as it does not happen at the time of full moon, there is no notice taken of it. When the moon's right ascension is equal to six signs, that is, when she is in or about the beginning of Libra, there is the greatest difference of the times of rising, viz. about an hour and 15 minutes. Those signs which rise with the least angle set with the greatest, and the contrary; therefore, when there is the least difference in the times of rising, there is the

greatest in setting, and vice versa. All this may be pleasingly exemplified by means of a celestial globe.

OF THE SATELLITES OF JUPITER.

259. The following table gives the periodical times and distances of Jupiter's satellites, and the angles under which their orbits are seen from the earth, at its mean distance from Jupiter.

Satellites.	*Days.*	*h.*	*min.*	*Dis. in miles.*	*Angles of orbit.*	
1	1	18	26.6	266.000	3′	55″
2	3	18	17.9	423.000	6	14
3	7	3	59.6	676.000	9	58
4	16	18	5.1	1.189.000	17	30

Obs. The third satellite is the largest of all; the first and fourth are nearly of the same size; the second is the smallest.

260. These satellites of Jupiter are of great use in astronomy. (1) In determining the distance of Jupiter from the earth. (2) They afford a method of demonstrating that the motion of light is progressive. And (3) from the eclipses of the satellites of Jupiter, we ascertain the longitude of different places.

261. OF THE SATELLITES OF SATURN.

Satellites.	Periodical terms.				Distance in miles.
1	1 day.	8h.	53′	8″	135.000
2	—	22	37	22	107.000
3	1	21	18	27	170.000
4	2	17	41	22	217.000
5	4	12	25	12	303.000
6	15	22	41	13	704.000
7	79	7	48	—	2.050.000

Obs. The 1st and 2d satellites were discovered by Dr. Herschel, in the years 1787 and 1788. To prevent mistakes he called them the 6th and 7th, though nearer to the planet than the other five. Dr. Herschel observes, that Saturn has probably a considerable atmosphere. It turns on an axis perpendicular to the ring, in 10h. 16′ 0.44″ and is flattened at the poles, so that the equatorial diameter is to the polar as 11 to 10.

OF THE SATELLITES OF HERSCHEL.

262. Dr. Herschel has at different times, discovered six satellites belonging to his new planet.

Satellites.	When discovered.	Periodical Times.			
1	Jan. 18, 1790	5d.	21h.	85′.	0″.
2	Jan. 11, 1787	8	17	1	19
3	Mar. 26, 1794	10	23	4	0
4	Jan. 11, 1787	13	11	5	1½
5	Feb. 9, 1790	38	1	49	0
6	Feb. 28, 1794	107	16	40	0

263. A ray of light is about eight minutes in coming from the sun to the earth.

Obs. From comparing the times of the apparent entrance and emersion of Jupiter's satellites, with tables calculated for the mean distances of the earth from the satellite, the visible emersion at the least distance of the planets is found to happen about 8 minutes sooner, and at the greatest distance about 8 minutes later, than by the tables: consequently, the ray of light is about 16 minutes in passing through the earth's orbit, or 8 minutes in coming from the sun to the earth. The diameter of the earth's orbit being 194,000,000 miles, the velocity of light will be

$$\frac{194{,}000{,}000}{16\text{-}|\text{-}60} = 202{,}088 \text{ miles in a second of time!}$$

OF COMETS.

264. Comets are opaque and solid bodies. A comet, at a given distance from the earth, shines brighter when it is on the same side of the earth as the sun, than when it is on the contrary side; from whence it appears that it owes its brightness to the sun.

Obs. 1. Of all the comets, the periods of only three are known with any degree of certainty. The first of these comets appeared in the years 1531, 1607, and 1782; and is expected to appear every 75th year. The second of them appeared in 1532 and 1661, and was expected to return in 1789, and every 129th year afterwards. The third, having last appeared in 1680, and its period being no less than 575 years, cannot return until the year 2225. This comet, at its greatest distance, is about 11,200,000,000 of miles from the sun; and its least distance from the sun's centre, which is 49,000 miles, is within less than a third part of the sun's semi-diameter from his surface. In that part of its orbit which is nearest the sun it moves at the rate of 880,000 miles an hour.

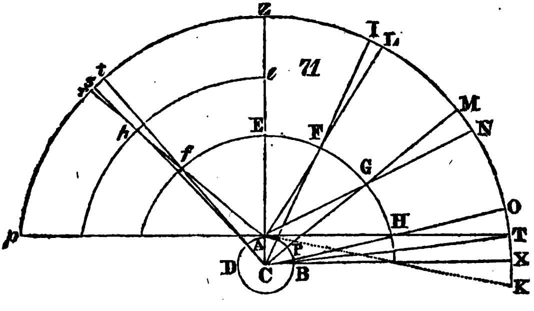
2. The Chinese astronomical books record the appearance of 2 or 300 comets.

3. The tail of the comet of 1680 was at least 100 millions of miles long; and that of 1812 was 30 millions of miles. Sir Richard Philips published in the Monthly Magazine the opinion that this wonderful appendage of comets, is occasioned by the refraction, and consequent condensation of the sun's light through the dense atmosphere of the comet: hence the tail is always in an exact right line opposite to the sun; and hence on the principle of a convex lens, the tail lengthens as it approaches the sun, and shortens as it departs.

OF THE PARALLAXES, DISTANCES, AND MAGNITUDES OF THE HEAVENLY BODIES.

265. The *Parallax* of the heavenly bodies, is the change of their apparent situation with respect to each other, as the spectator views them from different stations on the earth, or parts of the earth's orbit.

266. The *Diurnal Parallax* is the distance between the apparent place of a heavenly body, as viewed from the *surface* of the earth, and its apparent place, as viewed from the *centre* of the earth.



Obs. 1. Let DAB in fig. 71, be the earth, C its centre, A the station of a spectator on the surface of the earth; and F, G, H, different places of the moon, or any other heavenly body; TO, NM, LI, are its different parallaxes, and THO, or AHC; MGN, or AHC, &c. angles of parallax.

2. If a spectator in his first station at A, fig. 71 sees a planet at G, its apparent place in the heavens will be N; if now, by the diurnal rotation of the earth, he comes into the station P, the planet will appear at M, which is the place in which it would have appeared if viewed from C the centre: thus, in all cases, the parallax which arises from the diurnal motion, is the same which would arise from a change of station from the surface to the centre; for, in either case, the change of the spectator's line of view is the same. Hence appears the propriety of the above definition of the *diurnal parallax.*

267. The parallax of any planet is always proportional to the angle which a semi-diameter of the earth, drawn from the station of the spectator upon the surface to the centre, would subtend, if viewed from the planet.

Obs. 1. If the planet be at H, fig. 71, and the spectator at A, AHT will be his line of view; on changing the station of the spectator from A to C, the line of view will become CHO; whence TO will be the parallax. But TO subtends and is proportional to THO, or AHC, the angle which the earth's semi-diameter would subtend, if viewed from the planet H.

2. The parallax of a planet depresses its apparent place, by the parallactic arc. Thus, if the planet be viewed from C, fig. 71, its apparent place is O; if from A, its apparent place is T, farther from Z the vertex, than O, by the parallactic arc TO.

3. When the altitude of a body is observed, it must be corrected by parallax or refraction, adding the former, and subtracting the latter, in order to get the true altitude, or the altitude above the rational horizon at the centre of the earth.

268. The diurnal parallax of any planet, at a given distance from the earth, is greatest when the planet is in the horizon, and it decreases as the altitude of the planet increases.

Obs. 1. The parallax is proportional to the angle which AC, fig. 71, would subtend, if seen from the planet H: but this given line, viewed from the given distance of the planet, would continually diminish in its apparent magnitude, as the degree of obliquity at which it is viewed increases, that is, as the planet advances from H towards E; therefore, the parallax is greatest in the horizon, and decreases as the planet approaches the vertex. The parallactic angle AGC is less than AHC, and AFC less than AGC.

2. The moon's mean parallax is 57′.11″.

3. At the same altitude of different planets, their diurnal parallaxes are inversely as their distances from the centre of the earth, because the angles subtended by the semi-diameter will be mostly as the distances.

269. To measure the distance of the moon from the earth.

Def. The moon's *horizontal parallax* is the angle which a semi-diameter of the earth would subtend, if viewed directly from the moon.

Illus. Let H be the moon in the horizon observed by a spectator at A, fig. 71, and C the centre of the earth. In the triangle AHC, let the angle AHC, the moon's horizontal parallax, be found. The angle HAC is a right angle, and AC, the semi-diameter of the earth, is known to be 3985 miles.—Hence, AC the sine of AHC, 57′. 11″. is to 3935, as AH, taken as a radius, to the number of miles in HC, the moon's distance from the earth. The moon's mean distance is thus found to be 240,000 English miles.

Obs. According to M. de la Lande, the horizontal semi-diameter of the moon, is to its horizontal parallax for the mean radius of the earth as 15′. is to 54′. 57″. 4 or very nearly as 3 to 11: hence, the semi-diameter of the moon is 3-11ths of the radius of the earth. And as the magnitudes of spherical bodies are as the cubes of their radii, the magnitude of the moon is to that of the earth as 3^3 to 11^3, that is, as 1 : 49.

270. To determine the *relative* distances of the inferior planets from the sun.

Illus. If the elongation of Venus, or the greatest angle of Venus' distance, be found by observation; then, as a radius is to the sine of the angle, so is the distance of the earth to the distance of Mercury. If the sun's distance from the earth be supposed to be divided into 1000 equal parts, then the distance of Mercury, will in this manner be found to be 387, and that of Venus 723.

171. To determine the *relative* distances of the superior planets from the sun.

Obs. If the angle apparently performed by a superior planet, while the earth is moving from one end to the other of its axis, be determined by observation, then half that angle is the angle formed by the distance of the earth from the sun seen from the planet. Hence there is given that angle, the right angle at the sun, and the complement to 180°, *i.e.* three angles and the base 1000, the earth's distance, to find the perpendicular in a right angled triangle. If the mean distance of the earth from the sun be called 1000, that of Mars will be thus found to be 1523, that of Jupiter 5201, and that of Saturn 9538.

272. To find the parallax of the sun by the transit of Venus.

Obs. 1. This is one of the most important problems known to astronomy; because when the precise angle is known under which the semi-diameter of the earth is seen at the sun, a triangle is given of which one angle is 90° at the earth's centre, the other the parallax at the sun, (being the angle under which the earth's semi-diameter is seen,) and the other the complement of the same to 90°, and the base is the earth's semi-diameter known by measurement.

2. Venus would be seen like a dark spot on the face of the sun, as often as she passes in her orbit between the sun and the earth, but that the plane of her orbit does not coincide with the plane of the earth's orbit, and she passes in regard to the eye of a spectator at the earth, above or below the sun, except only when he happens to be in or near her nodes at the time of the conjunction. This, however, happens but seldom, the nearest transits to our time being in 1639, 1761, 1769, and 1814.

3. Nothing is more easy to be understood than the application of the phenomenon of a transit to ascertain the distance of the Earth from Venus and the Sun. All that is wanted is the angle presented at Venus, by any known portion of the earth's surface, and this is determined, by observing the exact time at which Venus enters or leaves the sun's face or disc at the two places, and then converting the difference of time (allowing for geographical difference,) into degrees, minutes, and seconds, which is of course, the parallax of Venus. Such is the general principle; but the details of the calculations are rendered complex by the various distances of observers, by their opportunities of observing, and by the compound motion of the Earth and Venus, in the intervals of observations. All these points are, however, susceptible of unerring calculation.

4. The parallax of Venus being thus determined, the sun's parallax is easily determined by the proportions indicated in article 278, and it appears to be 8 2-3 seconds, *i. e.* the same diameter of the earth equal to 3985 miles subtends at the sun an angle of 8.65 seconds, and by trigonometrical calculation, the perpendicular of the triangle, or the line joining the sun's and the earth's centre, is 95,173,000 miles, thus by logarithms e have 5.621914 (the sine of 8″. 65.) : 10.000000 :: 3.600428

(log. of 3985:) 95,173,000 miles. But some astronomers make the parallax somewhat more, and make it but 93 or 94 millions, while others make it less, or 96 millions.

273. To measure the distance of any planet from the sun.

Illus. Because the real distances of the planets from the sun are as their proportional distances; as the proportional distance of the earth from the sun is to the proportional distance of any other planet from the sun, so is the real distance of the earth from the sun in miles, to the real distance of any planet from the sun in miles.

Hence are found the distances of the planets from the sun in English miles. Mercury, 36,841,468; Venus, 68,891,486; Mars, 145,014,148; Jupiter, 494,990,976; Saturn, 907,956,139; and the Herschel 1800,000,000, all agreeable to the fact of the sun's parallax being 8 2-3 seconds.

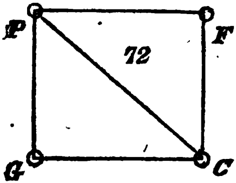
274. To find the periodical time of a planet.

Obs. Because the squares of the periodical times of the planets were found by Kepler to be as the cubes of their distances, the periodical times of any two planets being known, and the comparative or real distance of one of them from the sun being given, the distance of the other may from this proportion be found.

CAUSES OF THE PLANETARY MOTIONS.

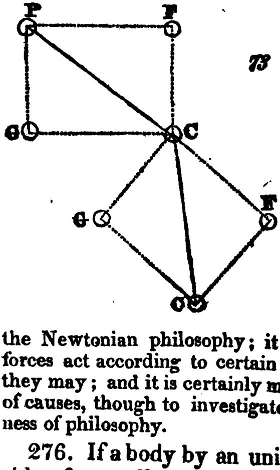
275. According to the Greeks, and the demonstrations of Newton, the planets are retained in their orbits by *gravitation*, which draws or impels them towards the centre of motion, and carried forward by a *projectile force*, which tend to carry them off at right angles to the other force, or in a tangent to their orbit.

Illus. 1. The motion of the primary planets is very simple and uniform, being compounded only of a projectile motion forwards in a straight line, which is a tangent to the orbit: and a gravitation towards the sun in the focus. The power which occasions the former is called a centrifugal force, and that which occasions the latter a centripetal one; and though gravitation is mutual between all the planets, being directly as the quantities of matter they contain, and inversely as the squares of their distances from each other; yet the motions of the planets are not much affected by it; for their quantities of matter are but very small when compared with that of the sun, and therefore its attraction, or their gravitation tow it, nearly destroys that of the planets one towards anoth



72

Illus. 2. Suppose P, fig. 72, a planet at rest, acted upon by a force which tends to carry it towards G, which force is directed towards a centre, and called the *gravitating force;* but at the same instant another force, acting at right angles to the former, tends to carry it towards F; the two forces will of course, by the laws of mechanical forces, carry it from P to C, in the diagonal of a square. If then the distances FP and PG are supposed to be infinitely small, or to represent the powers acting in the smallest conceivable portion of time, then the diagonal PC may be conceived to be an infinitely small portion of a circle, or a chord of a circle so small that it coincides with a circle.

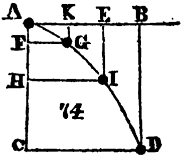


73

3. If then the action of the same forces be renewed at C in the directional CG towards the centre, and from CF at right angles, the planet will be turned into the diagonal CC, forming another small portion, chord, or increment of a circle, and the repetition of these impulses continued without ceasing, will, of necessity, carry the planet round the central body, in a circular orbit.

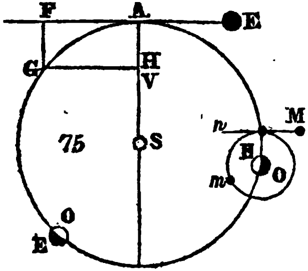
Obs. 1. The cause of gravitation or of projectile forces, is not affected to be explained by the Newtonian philosophy; it is simply assumed, that such forces act according to certain laws, let their causes be what they may; and it is certainly more safe to treat of effects than of causes, though to investigate the *latter* is the proper business of philosophy.

276. If a body by an uniform motion, describe one side of a parallelogram, in the same time that it would describe the adjacent side by an accelerated force, this body, by the joint action of these forces, would describe a curve terminating in the opposite angle of the parallelogram.

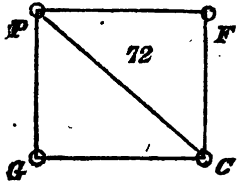


Let A B C D, fig. 74, be a parallelogram, and suppose the body A to be carried through A B by an uniform force, in the same time that it would be carried through AC by an accelerated force, then by the joint action of these forces, the body would describe a curve A G I D. For by the preceding illustration, if the spaces AE, EK, and KB, be proportioned to each other, the spaces AF, FH, and HC, will be in the same proportion, and the line AGID will be a straight line when the body is acted upon by uniform forces; but in this example, the force in the direction AB being uniform, would cause the body to move over equal spaces, AB, EK, and KB, in equal portions of time; while the accelerative force in the direction AC, would cause the body to describe spaces A F, F H, and H C, increasing in magnitude in equal successive portions of time; hence the parallelograms AEGF, AKIH, &c. are not about the same diagonal, therefore AGID is not a straight line, but a curve.

277. The curvilinear motions of all the planets, arise from the uniform projectile motion of bodies in straight lines, and the universal power called attraction, which draws them off from these lines.



Illus. If the body E. fig. 75, be projected along the line EAF, where it meets with no resistance, and is not drawn aside by any other force, it will (by the laws of motion) go on for ever in the same direction, and with the same velocity. For, the force which moves it from E to A in a given time, will carry it from A to F in a successive and equal portion of time, and so on; there being nothing either to obstruct or alter its motion. But if when the projectile force has carried the body to A, another body, as S, begins to attract it, with a power duly adjusted and perpendicular to its motion at A, it will be drawn from the straight line EAF,



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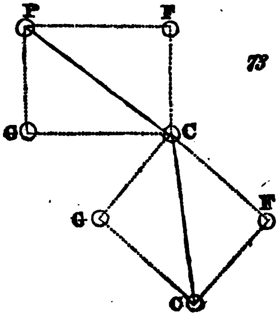

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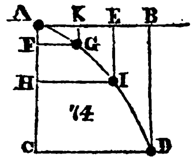

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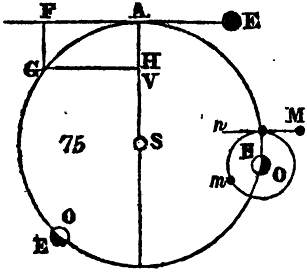

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OF THE FIXED STARS.

279. Those luminous points or bodies which always appear in the heavens at the same distance from each other, are called *Fixed Stars;* because they do not appear to have any proper motion of their own.

Obs. 1. The fixed stars are luminous bodies. Because they appear as points of small magnitude, when viewed through a telescope, they must be at such immense distance, as to be invisible to the naked eye if they borrowed their light; as is the case with respect to the satellites of Jupiter and Saturn, although they appear of very distinguishable magnitude through a telescope. Besides, from the weakness of reflected light, there can be no doubt but that the fixed stars shine with their own light. They are easily known from the planets, by their twinkling.

2. The number of stars, visible at any one time to the naked eye, is about 1000: but Dr. Herschel, by his skilful improvements of the reflecting telescope, has discovered that the whole number is great beyond all conception. The comparative brightness of the stars is Sirius 100, Canopus .98, Centauri 96, Acherni .94.

3. The magnitudes of the fixed stars appear to be different from one another, which difference may arise either from a diversity in their real magnitudes, or distances; or from both these causes acting conjointly. The difference in the apparent nitude of the stars is such as to admit of their being divided

into six clases, the largest being called stars of the first magnitude, and the least, which are visible to the naked eye, stars of the sixth magnitude. Stars only visible by the help of glasses, are called telescopic stars. Bode's catalogue contains 17,000 stars. Dr. Halley very justly remarks, that the stars must be infinite in number to maintain their equilibrium in space. And Dr. Herschel thinks he has seen stars 42,000 times as far off as Sirius. In one instance a cluster of 5000 stars, in a mass, were barely visible in the 40 foot telescope, and consequently must have been 11 trillions of miles off!

4. It must not be inferred that all the stars of each class appear exactly of the same magnitude: there being great latitude given in this respect; even those of the first magnitude appear almost all different in lustre and size. There are also other stars of intermediate magnitudes, which, as astronomers cannot refer to any one class, they, therefore, place them between two. *Procyon*, for instance, which PTOLEMY makes of the first magnitude, and *Tycho* of the second, FLAMSTEAD lays down as between the first and second. So that, instead of six magnitudes, we may say that there are almost as many orders of stars, as there are stars; such considerable varieties being observable in their magnitude, colour, and brightness.

5. To the bare eye the stars appear of some sensible magnitude, owing to the glare of light arising from the numberless reflections of the rays in coming to the eye; this leads us to imagine that stars are much larger than they would appear, if we saw them only by the few rays which come directly from them, so as to enter the eye without being intermixed with others. Examine a fixed star of the first magnitude through a long and narrow tube, which, though it takes in as much of the sky as would hold a thousand such stars, scarcely renders that one visible.

6. There seems but little reason to expect that the real magnitudes of the fixed stars will ever be discovered with certainty, we must, therefore, be contented with an approximation, deduced from their parallax, (if this should ever be ascertained,) and the quantity of light they afford us compared with the sun. To this purpose, Dr. HERSCHEL informs us, that with a magnifying power of 6450, and by means of his new micrometer, he found the apparent diameter of α Lyræ to be 0″.335, or the third of a second.

7. The ingenious observations of KEPLER upon the magnitudes and distance of the fixed stars, deserve to be introduced, as he has been followed in the conjecture by Dr. HALLEY. He

observes that there can be only 13 points upon the surface of a sphere as far distant from each other as from the centre; and supposing the nearest fixed stars to be as far from each other as from the sun, he concludes there can be only 13 stars of the first magnitude. Hence at twice that distance from the sun, there may be placed four times as many, or 52: at three times that distance, nine times as many, or 117; and so on. These numbers will give pretty nearly the number of stars of the first, second, third, &c. magnitudes. Dr. Halley farther remarks, that if the number of stars be finite, and occupy only a part of space, the outward stars would be continually attracted to those within, and in time would unite into one. But if the number be infinite, and they occupy an infinite space, all the parts would be nearly in equilibrio, and, consequently, each fixed star being drawn in opposite directions would keep its place or move on till it had found an equilibrium.

280. The ancients, that they might the better distinguish the stars with regard to their situation in the heavens, divided them into several constellations, that is, masses of stars, each mass consisting of such as are near each other. And to distinguish these groups from one another, they gave them the names of such men or things as they fancied the space they took up in the heavens represented.

Obs. 1. The following table contains the names of the constellations, and the number of stars observed in each by Flamstead.

		Flamstead.
Ursa minor - - -	The Little Bear - -	24
Ursa major - - -	The Great Bear -	87
Draco - - - - -	The Dragon - -	80
Cepheus - - -	Cepheus - - - -	35
Bootes - - -	Bootes - - - -	54
Corona Borealis - -	The Northern Crown -	21
Hercules - - -	Hercules kneeling - -	113
Lyra - - - -	The Harp - -	21
Cygnus - - -	The Swan - - -	81
Cassiopea - - -	The Lady in her chair	55
Perseus - - -	Perseus - - -	59
Auriga - - - -	The Waggoner - -	66
Serpentarius - - -	Serpentarius - -	74
Serpens - - - -	The Serpent - -	64

Sagitta	The Arrow	18
Aquila	The Eagle	71
Antinous	Antinous	
Delphinus	The Dolphin	18
Equulus	The Horse's Head	10
Pegasus	The Flying Horse	89
Andromeda	Andromeda	66
Triangulum	The Triangle	16
Aries	The Ram	66
Taurus	The Bull	141
Gemini	The Twins	85
Cancer	The Crab	83
Leo	The Lion	95
Coma Berenices	Berenice's Hair	43
Virgo	The Virgin	110
Libra	The Scales	51
Scorpius	The Scorpion	44
Sagittarius	The Archer	69
Capricornus	The Goat	51
Aquarius	The Water-Bearer	108
Pisces	The Fishes	113
Cetus	The Whale	97
Orion	Orion	78
Eridanus	Eridanus	84
Lepus	The Hare	19
Canis major	The Great Dog	31
Canis minor	The Little Dog	14
Argo Navis	The Ship	64
Hydra	The Hydra	60
Crater	The Cup	31
Corvus	The Crow	9
Centaurus	The Centaur	12
Lupus	The Wolf	24
Ara	The Altar	9
Corona Australis	The Southern Crown	12
Pisces Australis	The Southern Fish	24
Columbia Noachi	Noah's Dove	10
Robur Carolinum	The Royal Oak	12
Grus	The Crane	13
Phœnix	The Phœnix	13
Indus	The Indian	12
Pavo	The Peacock	14
Apus	The Bird of Paradise	11

		Flamstead.
Apsis	The Bee or Fly	4
Chamæleon	The Cameleon	10
Triungulum Australis	The South Triangle	5
Piscis Volans	The Flying Fish	8
Dorado	The Sword Fish	6
Toucan	The American Goose	9
Hydrus	The Water Snake	10
Lynx	The Lynx	44
Leo minor	The Little Lion	53
Asterion & Clara	The Greyhound	25
Cerbereus	Cerberus	
Vulpecula & Anser	The Fox and Goose	35
Scutem Sobieski	Sobieski's Shield	
Lacreta	The Lizard	16
Camelopardalus	The Cameleopard	58
Monoceros	The Unicorn	31
Sextans	The Sextant	41

2. Stars not included in any constellation are called *unformed* stars. Besides the names of the constellations, the ancient Greeks gave particular names to some single stars, or small collections of stars: thus the cluster of small stars in the neck of the bull, was called the *Pleiades;* five stars in the bull's face, the *Hyades;* a bright star in the breast of *Leo*, the *Lion's Heart;* and a large star between the knees of *Bootes*, *Arcturus.*

3 Greek letters have been added by Bayer to stars in the several constellations of his catalogue (α being affixed to the largest star) by means of which any star may be easily found.

4. Twelve of these constellations lie upon the ecliptic, including a space about fifteen degrees broad, called the *Zodiac*, within which all the planets move. The constellation Aries, about 200 years ago, lay in the first sign of the ecliptic; but on account of the precession of the equinoxes, it now lies in the second. In the foregoing table *Antinous* was made out of the unformed stars near *Aquila:* and *Como Berenices* out of the unformed stars near the *Lion's* tail. They are both mentioned by PTOLEMY, but as unformed stars. The constellations as far as the triangle, with *Coma Berenices*, are *northern;* those after *Pisces*, are *southern.*

5. The luminous part of the heavens, called the *Milky Way*, consists of fixed stars too small to be seen by the naked eye. In a paper on the constructions of the heavens, Dr. Herschel says it is very probable, that the great stratum called the milky way, is that in which the sun is placed, though per-

haps not in the centre of its thickness, but not far from the place where some smaller stratum branches from it. Such a supposition will satisfactorily, and with great simplicity, account for all the phenomena of the milky way, which, according to this hypothesis, is no other than the appearance of the projection of the stars contained in this stratum, and its secondary branch.

6. In another paper on the same subject, he says,—We will now retreat to our own retired station in one of the planets attending a star in the great combination with numberless others; and in order to investigate what will be the appearances from this contracted situation, let us begin with the naked eye. The stars of the first magnitude, being, in all probability, the nearest, will furnish us with a step to begin our scale; setting off, therefore, with the distance of Sirius or Arcturus, for instance as unity, we will at present suppose, that those of the second magnitude are at double, and those of the third at treble the distance, and so forth. Taking it then for granted, that a star of the seventh magnitude is about seven times as far from us as one of the first, it follows that an observer, who is enclosed in a globular cluster of stars, and not far from the centre, will never be able, with the naked eye, to see the end of it: for since, according to the above estimations, he can only extend his view about seven times the distance of Sirius, it cannot be expected that his eyes should reach the borders of a cluster, which has, perhaps, not less than fifty stars in depth every where around him. The whole universe, therefore, to him, will be comprised in a set of constellations, richly ornamented with scattered stars of all sizes. Or if the united brightness of a neighbouring cluster of stars should, in a remarkable clear night, reach his sight, it will put on the appearance of a small, faint, nebulous cloud, not to be perceived without the greatest attention. Allowing him the use of a common telescope, he begins to suspect that all the milkyness of the bright path which surrounds the sphere may be owing to stars. By increasing his power of vision, he becomes certain, that the milky way is, indeed, no other than a collection of very small stars, and the nebulæ nothing but clusters of stars.

7. Dr. Herschel then solves a general problem for computing the length of the visual ray: that of the telescope, which he uses, will reach to stars 497 times the distance of Sirius. Now Sirius cannot be nearer than 100.000X190.000,000 miles, therefore Dr. Herschel's telescope will at least, reach to 100.000

X190.000.000.X497 miles. And Dr. Herschel says, that in the most crowded part of the milky way, he has had fields of view that contained no less than 588 stars, and these were continued for many minutes, so that in a quarter of an hour, he has seen 116,000 stars pass through the field view of a telescope of only 15′. aperture; and at another time, in 41 minutes, he saw 258,000 stars pass through the field of his telescope. Every improvement in his telescope has discovered stars not seen before, so that there appears no bounds to their number, or to the extent of the universe.

8. There are spots in the heavens, called *Nebulæ*, some of which consist of clusters of telescopic stars, others appear as luminous spots of different forms. The most considerable is one of the mid way between the two stars on the blade of Orion's sword, marked θ by Bayer, and discovered in the year 1656 by Huygens; it contains only seven stars, and the other part is a bright spot upon a dark ground. To Dr. Herschel, we are indebted for catalogues of 2000 nebulæ and clusters of stars which he himself had discovered. Some of them form a round compact system, others are more irregular, of various forms, and some are long and narrow. The appearance of luminous spaces in the heavens Sir Richard Philips denies to arise from light per se; but ascribes the luminosity of all such spaces to the multitude of planets, asteroids, satellites, and cometary bodies, with which those spaces are filled.

9. New stars sometimes appear, while others disappear. Several stars, mentioned by the ancient astronomers, are not now to be found: several are now visible to the naked eye, which are not mentioned in the ancient catalogues; and some stars have suddenly appeared, and again, after a considerable interval, vanished: also a change of place has been observed in some stars. Dr. Herschel has observed the motions of nearly fifty stars, with reference to others in their vicinity. Castor he finds has a period of 342 years; Gamma Leonis, of 1200 years; Epsilon Bootes, of 1681 years; Delta Serpente, of 375 years; Gamma Virginia of 708 years; and so of others: but the life of one man is evidently too short to attain correct results, in regard to periods so disproportionate to his narrow space of existence.

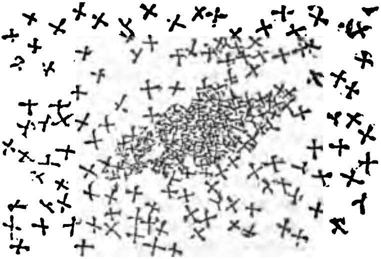
10. These motions of the stars among themselves being apparent to observation, the doctrine of Dr. Herschel and other astronomers is rendered probable, that the sun has a motion or orbit of its own among the fixed stars of the milky way, at the rate of the earth's motion, carrying with it all the planets, just as the planets themselves, carry with them their systems of sa-

tellites in their own orbits. The rotation of the sun on its inclined axis, according to the theory of Sir Richard Philips, seems to indicate the action of a centrifugal force in the sun, and to render the notion, that the whole solar system is analogous to a primary and its satellites, exceedingly probable.

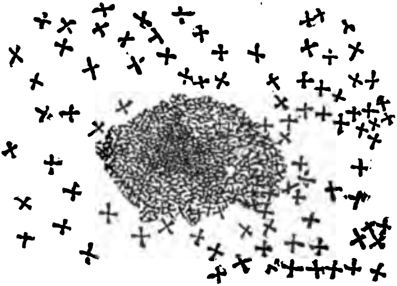
11. From an attentive examination of the stars with good telescopes, many which appear only single to the naked eye, are found to consist of numerous stars. *α Herculis*, is a double star, *π Bootis*, and Dr. Herschel, by his highly improved telescopes, has found about 700.

12. In February, 1814, Dr. Herschel, the prince of astronomers, read to the Royal Society, the results of thirty years' observations on Nebulæ, with the best telescopes ever possessed by man. He conceives that the stars form independent systems among themselves. He considers our sun as part of that shoal or system which we call the milky way, and that all the stars of the first, second, and third magnitude, belong to that vast cluster. The stars, he remarks, are not spread in equal portions over the horizon, but are found in patches, each containing many thousands, and many more than the eye can separate from the mass. These he calls clusters; and he conceives they have a constant disposition to unite more closely, by a power which he calls the clustering power; doubtless the same power which is described in the observation to article 276. He gives an account of eighty of these clusters, some of the drawings of which are copied here.

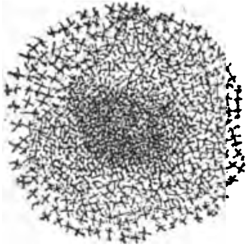
The following figure represents a COMPRESSED CLUSTER OF STARS, the centre part 8′ long 2′ broad.



The following figure represents another similar CLUSTER of STARS.



The following figure represents a GLOBULAR CLUSTER 2′ in diameter, as seen with Herschel's 40 feet telescope.



281. The *Annual Parallax* of a heavenly body, is the change of its apparent place, as it is viewed from the earth in its annual motion; and is the angle which the diameter of the earth's orbit would subtend, if that diameter was viewed from that body.

282. If the distance of an object be greater than 100,000 times the base, the angles at the stations will not sensibly differ from right angles; consequently, the lines drawn from the object to the stations, are, physically speaking, parallel, and the parallax of an object, the distance of which is above 100,000 times greater than that between the two stations of observation, is consequently insensible.

Obs. If the object be at a greater distance from either station than 100,000 times the base, the angle at one of the stations being 90°, the angle at the other will be more than 89° 59′ 57″. 9, the difference of which angle and 90° being scarcely more than 2″, is too small to become sensible by observation.

283. If the parallax of an object (observed with an instrument sufficiently exact to measure an angle of $2''$.) be insensible, the distance of the object from either station cannot be *less* than 100,000 times the base, yet it may be greater in assignable ratio.

Obs. Lines drawn from any given points in a base, to an object, may be esteemed in practice, parallel, without any sensible error, if the distance of the object be more than 100,000 times the base. Rays, therefore, diverging from any point in the sun's disc upon the surface of the earth, may be esteemed parallel, if their distance from each other do not exceed about 970 miles at the earth's surface: because 970 is to the distance of the earth from the sun in a proportion of 1 to 100,000.

284. The fixed stars have no sensible annual parallax, because when the place of any star is observed by the best instruments, from opposite points or ends of the earth's orbit, its apparent place in the heavens remains the same, which could not be the case, if the angle of its parallax were so much as *two seconds.*

Obs. 1. Hence it appears that the fixed stars are so remote, that a diameter of the earth's orbit bears no proportion to their distance, or that a diameter of the earth's orbit, if viewed from one of the fixed stars, would appear as a point.

2. The distance of the stars must be greater than 100,000 times the base, from the extremities of which it is observed, that is, greater than 100,000 times the diameter of the orbit of the earth, or greater than $100,000 \times 190,000,000$, which is nineteen billions of miles as the least possible distance of the nearest fixed star.

3. The parallax of a fixed star, being not more than $2''$. the sun, when viewed from that star, would appear under an angle less than $\frac{32' 6''}{200,000,}$ or less than $\frac{1''}{100,}$ and, therefore, could not be distinguished from a point.

4. Since bodies equal in magnitude and splendour to the sun, being placed at the distance of the fixed stars, would appear to us as the fixed stars now do, it may be supposed probable, that the fixed stars are bodies similar to the sun, which is the centre to the solar system. This being the case, the reason will appear, why a fixed star, when viewed through a telescope magnifying 200 times, appears no other than a point. For the apparent diameter of the star being less than 1-100 part of a

second when magnified 200 times, will subtend an angle less that 2″. at the eye of the spectator, observing it in the telescope.

5. The parallax of the fixed star, when viewed from the opposite parts of the earth's orbit, is here assumed 2″. but it is probable that the parallax of the nearest star is much less, and consequently the distance greater, in the same proportion as the parallax is less. Dr. Bradley thought that if the parallax of a fixed star had been *one second*, he should have been able to detect it. The diameter of the earth's orbit is, therefore, but a point at the fixed stars. Nor is this wonderful, for the immense distance of the stars themselves is but a point compared with the *infinite* extension of space. Doubtless, the stars in the clusters seen by Herschel, are as distant from each other, as the fixed stars of our cluster of the milky way, are found to be from each other, yet those clusters seen from the earth are but points! No considerations can be more wonderful or sublime!

QUESTIONS ON ASTRONOMY.

What is *astronomy?*

What constitutes the *solar system ?*

What are the names of the *primary planets* composing the solar system ?

What are the names of the *asteroids ?*

What is the number of the secondary planets, and to what primary planets do they belong ?

Explain the solar system.

What was the system of Ptolemy ?

How is it demonstrated that the planets move round the sun ?

How are the motions of the earth in its orbit proved ?

How is it proved that the Earth is of a globular form ?

What is the *axis* of the earth ?

What are the poles ? and what the *equator ?*

What are the *arctic* and *antarctic* circles ?

What are the *tropics ?*

What are the *zones ?*

What is *latitude*, and what is *longitude ?*

Explain the figure of the *celestial* globe ?

What are the *poles* of the *horizon*, and what are they called ?

What is meant by *meridian ?*

What is *altitude*, what *azimuth*, and what *amplitude ?*

What is meant by *declination*, and what by *right ascension ?*

When are two planets said to be in *conjunction* and when in *opposition?*

When is the celestial sphere said to be *right*, *oblique*, or parallel?

How is *day* and *night* produced?

How long is the earth in performing a revolution round the sun?

What are the 12 *signs* of the *zodiac?*

What are the names of the signs, and which are *north* and which *south* of the equator?

Explain figure 64. What is the *ecliptic?*

What is the quantity of the angle made by the inclination of the ecliptic to the equator?

To what is the diminution of the obliquity of the ecliptic owing?

What is the *nutation* of the earth's axis, and to what cause is it owing?

How may the difference of *longitude* in two places be found?

Explain this.

Explain prop. 210, also 211, and 212.

What causes the succession of seasons?

What is the figure of the earth's orbit?

What occasions twilight?

Explain.

How is it that we see the sun before he actually rises above the horizon?

What is a *natural* day?

What is equation of time?

What is meant by mean, or apparent time?

What is the shape of the sun, and where is he placed?

What is his diameter?

Has the sun an atmosphere?

What is the calculation of Euler in regard to the comparative light of the sun?

How has the period of the sun's revolution about its axis been determined? What is this period?

What is Dr. Herschel's opinion of the height of the sun's atmosphere?

What comparative quantities of matter does the sun and Jupiter contain?

How much larger is the sun than the earth?

What is the probability that the sun is inhabited?

What is the distance of the sun from the earth?

Why are the asteroids called *telescopic* planets?

Explain figure 67.

What is meant by *aphelion* and *perihelion* distance?

What is *apogee* and *perigee*?

How will you show that a planet does not proceed in its orbit with an equable motion?

What is a planet's *anomaly*?

Calculate the true place of a planet.

What is meant by the *equation* of a planet's centre?

What is a planet's *elongation*?

What is *periodic time*? and what is meant by *tropical* and *sidereal revolution*?

What is a planet's *direct* motion, and why does it sometimes appear *stationary*, and sometimes to move in a contrary direction?

What are the *nodes*?

What is the diameter of *Mercury*?

What is the period of its sidereal revolution?

What is the greatest elongation of this planet from the sun?

What is meant by its transit?

How much greater is the sun's heat and light at Mercury than with us?

What is the diameter of Venus?

What is the period of its sidereal revolution?

What is its period of revolution on its own axis?

When does Venus appear brightest?

When is this planet the morning and when the evening star?

What is the diameter of the earth?

What are the periods of its two revolutions?

What effect does its *centrifugal* force have on the weight of bodies?

If the motion of the earth was seventeen times greater than it is, what would be the effect on the weight of bodies?

What is the velocity with which a place moves per minute at the equator?

Calculate the velocity of Philadelphia.

What is the shape of the earth?

What is the difference between the *equatorial* and the *polar* diameter of the earth?

How is it determined that the earth is flattened at the poles?

Why are bodies heavier at the poles, than at the equator?

Why is the *periodical* year longer than the *tropical*?

What causes the *precession* of the equinoxes?

How often does the *tide* rise and fall?

What is the cause of tides?

Draw a figure illustrating the theory of tides.

Why are the tides greatest at the new and full moons? and why least at the first and last quarters, and why are they highest of all about the time of the equinoxes?

Explain prop. 220.

What is the diameter of Mars?

What is its period of revolution about its axis, and what is its sidereal period?

What are the names and diameters of the several *asteroids*?

What is the sidereal period of each?

What is said of the origin of asteroids?

What is the diameter of Jupiter?

What is its diurnal, and what its sidereal period?

How many satellites has this planet?

What is said of Jupiter's belts?

What is the diameter of Saturn?

What is its diurnal, and what its sidereal period?

How many *moons* has Saturn?

What is said of Saturn's ring?

To what distance does the atmosphere of Saturn extend?

What is the diameter of Herschel, what its sidereal revolution?

When and by whom was this planet discovered?

Mention the names of the planets in succession, beginning with that nearest the sun.

What is an easy distinction between a planet and a fixed star?

What are secondary planets?

Why are the motions of the secondary planets less uniform than those of their primaries?

What is the diameter of the moon?

What its mean distance from the earth?

What is the period of its sidereal revolutions?

What is meant by *synodic* revolution?

What is meant by the moon's *Syzygies?*

Explain prop. 243, making use of the plate which illustrates it.

Why is the moon sometimes invisible when it is above the horizon?

How many days complete the year at the moon?

How many of our days is equal to one at the moon?

Explain prop. 247.

What is said of the excentricity of the moon's orbit?

How is it proved that the moon is diversified with hills and valleys?

What does Dr. Herschel say in regard to the mountains of the moon, and the volcanoes which he saw there?

What occasions an eclipse of the moon?

Illustrate this by explaining the figure.

If the earth were as large as the sun, what different phenomena would happen in regard to eclipses?

When is an eclipse of the moon *partial*, and when *total*, and what occasions this difference?

What are the relative positions of the sun, moon, and earth, when an eclipse of the *sun* happens?

When does a total eclipse of the sun happen, and what occasions it?

Why is there not an eclipse of the sun at every new moon?

What is the average number of eclipses per year, of the sun and moon?

Explain the phenomena of the *harvest* moon.

What are *comets?*

How many comets are known to return at certain periods?

What is meant by the *parallax* of a heavenly body?

What is the *diurnal parallax?*

How are the parallaxes of the planets calculated? Explain the figure.

How are the relative distances of the planets from the sun determined?

How do you measure the distance of any planet from the sun? What is the rule?

Find the periodical time of a planet.

Account for the curvilinear motions of the planets.

Explain prop. 279.

Why are some of the stars called *fixed stars?*

How is it proved that the fixed stars shine with their own light?

What number of stars are visible at any one time to the naked eye?

What is said of the distance and number of the fixed stars?

What is the use of dividing the stars into constellations?

Are all the stars included in the several constellations?

What gives the appearance called the *milky way?*

What are the spots in the heavens called *nebulæ?*

What is said concerning the appearance of new stars?

What are the principles on which the parallax of a heavenly body is determined?

Why have not the fixed stars a sensible annual parallax?

What inference is drawn from the fact, that the fixed stars have no annual parallax?

OF ELECTRICITY.

285. The surface of the earth and of all the bodies with which we are acquainted, is supposed to contain or possess a power of exciting or exhibiting a certain quantity of an exceeding subtile agent, *called the electric fluid or power.*

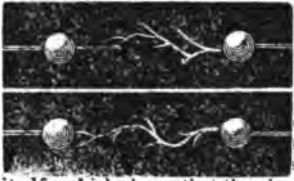
286. The quantity usually belonging to any surface, is called its natural share, and then it produces no sensible effects; but when any surface becomes possessed of *more*, or of *less*, than its natural quantity, it is electrified, and it then exhibits certain appearances ascribed to the *power*, called *electric.*

Experiment 1. Take a stick of sealing wax and rub it with your hand, or with a piece of flannel, or on your coat sleeve, and it will have the power of attracting small bits of paper, or other very light substances, when held near them.

2. If a clean and dry glass tube be rubbed several times upwards and downwards, and then presented to any small light substance, it will immediately attract and repel them alternately for a considerable time. The tube is then said to be *excited.*

3. If a glass tube be rubbed several times in the dark, and then brought within about half an inch of the finger, a lucid spark will be seen between the finger and the tube, accompanied with a snapping noise, and the finger at the same time will perceive the sensation of a prick from a pin. The attraction, repulsion, sparkling, and noise, are the effects of electricity, and are denominated electrical appearances.

The following figure represents the appearance of Sparks of Electricity.



4. If an oblong piece of metal, such as a poker, be suspended by means of a dry silk string, and the excited glass tube be presented to its upper end, then the lower end of the metallic body will exhibit the same phenomenon as the tube itself, which shews that the electric fluid passes through the metal.

5. If instead of the metallic body, a stick of glass, or sealing wax, be suspended, none of these phenomena will be exhibited, which proves that the electric fluid does not pass through these substances.

287. All those bodies which transmit or conduct electricity from one surface to another, are called *conductors*; and those surfaces that will not transmit the electric power, are called *electrics* or *non-conductors*.

288. The metals, semi-metals, and metallic ores, are conductors of electricity; so are charcoal, water, and other fluids, except the aerial fluids and oil. Almost all saline, and many earthy substances, are likewise *non-electrics* or *conductors*.

289. The following substances are *electrics* or *non-conductors*, viz. vitrified substances, amber, sulphur, resinous substances, wax, silk, cotton, feathers, wool, hair, paper, elastic fluids, sugar, oil, metallic oxydes, animal and vegetable ashes, dry vegetable substances, &c.

290. When a surface is supposed to have more than its natural quantity of this fluid, it is said to be *positively* electrified; when it is supposed to have less than its natural share, it is said to be *negatively* electrified.

291. When any electrified *conductor* is wholly surrounded by *non-conductors*, so that the electric fluid cannot pass from the conductor along conductors to the earth, it is said to be *insulated*.

Exp. The human body is a good conductor of electricity; but if a person stand on a cake of resin, or on a stool supported by glass legs, the electric fluid cannot pass from him to the earth; and if he is touched by another standing on the ground, he will exhibit sparks.

292. The principal method of exciting the electric fluid is by *contact*, *pressure*, or *friction*. When an electric and non-electric are rubbed against each other, electricity is excited, and the electric power passes from the non-electric or conductor, to the electric or non-conductor.

Exp. 1. If a smooth glass tube be rubbed with the hand; the electric fluid will leave the hand, and pass upon the tube, which will then have more than its natural quantity.

2. And if the finger, or any conducting substance, be presented to the tube, the electricity will then pass to it.

Obs. Certain changes in the forms of substances, are always connected with electrical effects. Thus, when vapour is formed, or condensed, the bodies in contact with the vapour become electrified. If, for instance, a plate of metal be strongly heated, and *a drop of water be then poured upon the plate,* at the moment the water rises in vapour, the gold leaves of the electrometer will diverge with negative electricity. Sulphur, after being melted, becomes strongly electrical during the time of congelation.

293. Two surfaces, both positively, or both negatively electrified, mechanically *repel* each other; and two substances, of which one is positively, and the other negatively electrified, mechanically *attract* each other.

294. If any person who is *insulated*, rubs a glass tube, the person and the glass tube will become electrified, and be capable of attracting and repelling light bodies; but the electricity of the person will differ from that of the tube.

Exp. 1. Let two cork balls, connected by a linen thread, be held by a silk thread, attached to the middle of the former, at some distance from a wall; then bring the excited tube near the balls, and it will first appear to attract, and soon after repel them; this apparent repulsion will continue for a considerable time, though the tube be removed.

2. Let another pair of cork balls be brought in contact with the insulated person, and they will appear to repel each other.

3. But if the two pair of balls be brought near, they will attract each other, and the electrical power will disappear;

which shews that there are two electricities, one being the reverse of the other, and seeming to have what the other wants.

4. If the insulated person rub a stick of sulphur, or resin, or sealing-wax, that substance will acquire the electricity which, in the preceding experiment, was acquired by the insulated person.

5. Hence *positive* and *negative* electricity have sometimes been called *vitreous* and *resinous*.

295. Opposite electricities always accompany each other, for if any surface become positive, the surface with which it is rubbed becomes negative ; and if any surface be rendered positive, the *nearest* conducting surface will become negative.

296. When one side of a metallic or other conductor receives the electric fluid, its whole surface is instantly pervaded ; whereas when an electric is presented to an electrified body, it becomes electrified on a small spot only.

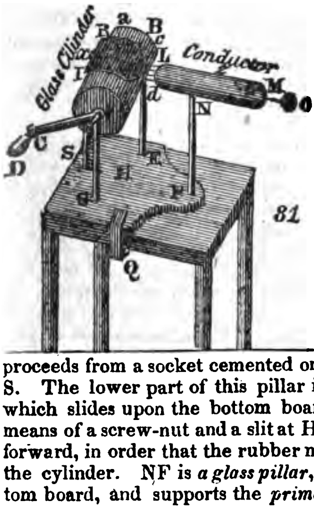
Obs. There is a stone found in many parts of the world called *tourmalin*, which is sometimes crystalized as a nine-sided prism, terminated by a three-sided and a six-sided pyramid ; when this substance is gently heated, it becomes electrical, and one extremity, that terminated by the six-sided pyramid, is positive, the other is negative ; to a certain extent, its electricities are exalted by increasing the temperature ; when it begins to cool, it is still found electrical, but the electricities are changed ; the pyramid, before positive, is now negative, and vice versa. When the stone is of considerable size, flashes of light may be seen along its surface. There are other gems and crystalized substances, which possess a property similar to that of the tourmalin. The luminous appearance of some diamonds, when heated, probably depends upon their electrical excitation. The substance called the *boracite*, which is a cube, having its edges and angles defective, becomes electrical by heat, and in one variety presents no less than eight sides, in different states, four positive, four negative ; and the opposite poles are in the direction of the axis of the crystal.

297. If to one side of an electric, viz. a pane of glass, you communicate positive electricity, the opposite side will become negatively electrified, and the late is then said to be *charged*.

Obs. The positive and negative electricities, in the above case, cannot come together, unless a communication, by means of conductors, is made between the sides of the glass; and in like manner as a plate of glass is charged, so the plate of air lying between any electrified surfaces is always charged.

298. When two surfaces oppositely electrified, are united, their powers are destroyed, and if their union be made through the human body, it produces an affection of the nerves called *an electric shock.*

299. Machines have been contrived for rubbing together the surfaces of electrics and non-electrics, and for collecting the electric fluid, when so excited.



81

Illus. 1. Fig. 81, represents an *electrical machine.* G E F is a strong board, which supports all the parts of the machine, and which may be fastened to a table by means of one or more iron, or brass clamps, as Q. The *glass cylinder* d B is supported by the *two glass legs*, G and E. IR is the rubber of leather, and silken flap. The rubber is spread with an amalgam of mercury and zinc, or tin. The rubber or cushion is fastened to a spring, which proceeds from a socket cemented on the top of the *glass pillar* S. The lower part of this pillar is fixed into a small board, which slides upon the bottom board of the machine, and by means of a screw-nut and a slit at H, may be fixed more or less forward, in order that the rubber may press more or less upon the cylinder. NF is *a glass pillar*, which is fixed in the bottom board, and supports the *prime conductor* ML of hollow brass, or tin plate, or coated wood, which has a collection of *pointed wires* at L, and *knobbed wire* at M. From the *brass knob* O a longer spark may be drawn with the hand than from any other part of the conductor.

2. When the cylinder is turned swiftly, the friction of the glass against the rubber causes the electric fluid which was up-

on the rubber to pass to the glass, from whence it is conveyed to the points of the prime conductor, which are presented to every part of the cylinder in succession. If one end of the chain be put on the knob x and the other end hang on the ground, there will then be a constant supply of the electric fluid to the prime conductor, which will be discharged in sparks to any body presented to it. The *rubber* is re-supplied by means of the surfaces in immediate contact, and these again are supplied by the general mass of the fluid that is lodged on the earth.

300. Bodies or surfaces, that are charged with the same electricity, appear to *repel* each other; but if one have more and the other less than its share, they will appear to *attract* one another.

Exp. 1. If a tuft of feathers be hung on the prime conductor LM, fig. 81, the moment they are electrified by turning the wheel of the machine, they will endeavour to avoid one another and stand erect: because, being all electrified by the same electricity, they repel each other.

2. A large feather will, if placed in the hole s, when the machine is worked, become beautifully turgid, expanding its fibres in all directions: and they collapse when the electricity is taken off, by presenting any conducting substance to them.

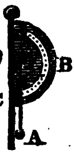
3. Excite a glass tube eighteen or twenty inches long, then present to it a small feather, which will first have the appearance of being attracted by it, and afterwards jump from it. If no other body happens to be in the way, it will tend towards the ground; but if the tube be held under it, it will be still repelled, and may be driven about for a considerable time.

4. Suspend a plate of metal from the conductor, and underneath it, at the distance of about three or four inches, put another plate of the same size; upon the lower one small feathers, pieces of paper, &c. may be placed; these will, as soon as the machine is worked, jump to the plate, from which they will be repelled and fly to discharge themselves upon the lower plate, after which they will be attracted and repelled again, and so continue till the electricity of the upper plate is completely discharged.

5. If two balls made of cork, or the pith of elder, about the size of large peas, be fastened to silk threads, they will hang parallel to each other, and be in contact; but when brought near the electrified prime conductor, they will strongly repel each other.

6. These balls, in their electrified state, shew whether the electricity is positive or negative; for if it be positive, by applying an excited stick of sealing-wax, the thread will collapse; but, if it be negative, the sealing-wax will make them recede still farther.

301. A pair of cork or pith balls, or pieces of gold-leaf, are used to discover the presence or strength of electricity, and denominated an *electrometer*.


82

Exp. Fig. 82, represents a *quadrant* electrometer, which may be fixed in the hole *s* of the prime conductor, fig. 81. It consists of a very light rod, and pith ball A, turning on the centre of a semicircular B. According to the strength of the electricity the pith ball flies up, and the scale marks the degree in which the prime conductor is electrified.

302. If a surface, containing only its natural share of electricity, be brought near a body that is electrified, positively or negatively, a part of the opposite electricity, in the form of *a spark*, will force itself through the air, from the latter to the former.

303. When two surfaces, one electrified positively the other negatively, approach each other, the superabundant electricity rushes violently from one to the other, to restore the equilibrium.

Obs. It rushes, says Sir Richard Phillips, through the nearest point of physical contact, usually some spicula on the surface, and in this spicula or point is consequently concentrated the entire power of the opposing surfaces. Hence the positive side exhibits brushes at the points, diverging, diffusing, and vanishing; and the negative a concentrated and uniting star.

304. If an animal be placed so as to form part of this circuit, the electricity in passing through it produces a sudden and violent sensation, called the *electric shock*.

305. The motion of electricity, in passing from a positive to a negative body, is so rapid, that it appears to be, in truth must be, *instantaneous*.

Obs. The writer referred to above, says it is analogous to light and shade, and therefore necessarily coincident.

306. When any part of one side of a glass is presented to a body electrified positively or negatively, that side of the glass becomes possessed of the *contrary* kind of electricity to the side of the body it is presented to, and the other side of the glass is possessed of the same kind of electricity as the other body.

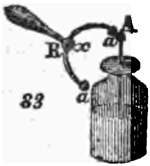
Exp. If the knob O of the prime conductor, fig. 54, be electrified positively, and a pane of glass be presented to the side next to O, it will be negatively electrified, and the other side will be positively electrified.

307. Electricity may be communicated to the whole surface of glass, or any part of it, if it be covered with a metallic substance, as *tin-foil;* and this is called *coating* the glass.

308. If a conducting communication be made between both sides of the glass thus *coated* and *charged* with electricity, a discharge or explosion takes place.

Obs. Glass of any form, provided it be sound, will answer the purpose; but cylindrical jars are chiefly used.

309. A glass bottle, or jar properly coated for electrical purposes, is called a *Leyden* phial, or jar, from the city where this property was first discovered.



83

Illus. Fig. 83, represents a Leyden jar coated with tin-foil on the inside and outside, within about three inches of the top of its cylindrical part, and having a wire with a round brass knob, or ball, A, at its extremity. This wire passes through the cork, or wooden stopper, and at its lowest extremity is a piece of chain that touches the inside coating in several parts. To charge this jar, a communication is made between the electrical machine and the brass knob A, while the outside of the jar communicates with the earth by the table or the hand.

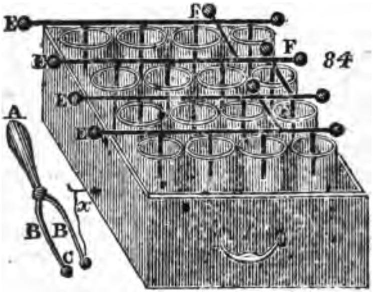
Exp. 1. Bring the knob A of the jar near the prime conductor, and after a few turns of the machine the jar will be charged: that is, the inside of the jar will be positively, and the outside negatively electrified; or if the inside is negatively, the outside will be positively electrified. R is a discharging rod, which is used to convey the superabundant electricity from one side to the other, where there is less than the natural share. The discharging rod consists of two brass knobs *a a* attached to wires, which move round a joint *x*, fixed to a glass handle R.

2. When one of the knobs is applied to the ball A, and the other to the outside coating, a communication is made between the outside and inside of the jar, by which the equilibrium is instantly restored by the superabundant electricity passing from one side to the other, appearing in the form of a vivid flash, accompanied with a loud report.

3. A shock may be taken by putting one hand to the outside coating, as at *a*, and bringing the other to the knob A.

4. Any number of persons may receive the shock together by laying hold of each others' hands, the person at one end touching the outside of the jar, and the person at the other end bringing his hand near the knob A. If there were a hundred persons so situated, they would every one feel the shock at the same instant. The electric fluid may be thus conveyed many miles in a moment of time.

310. Several Leyden jars, connected together by making a communication between ***all the outsides***, and another communication between ***all their insides***, form an ELECTRICAL BATTERY.



84

Illus. Fig. 84, represents a battery, consisting of sixteen jars, coated with tin-foil, and disposed in a proper box. The wires, which proceed from the inside of every four of those jars, are screwed, or fastened, to a common horizontal wire E, which is knobbed at each extremity, and by means of the wires F, F, F, the inside coating of 4, 8, or 12, or of all the sixteen jars may be cemented. The inside of the box, which contains these jars, is lined with tin-foil. On one side of this box there is a hole, through which a strong wire or hook passes, which communicates with the lining of the box, and of course, with the outside coating of the jar. To this hook a wire is occasionally fastened, which connects it with one branch of the discharging rod, B B C A.

311. By means of the battery, electricity is capable of producing the most powerful effects.

Exp. 1. A very slender wire, as *x*, being made part of the circuit, will, by the discharge of the battery, instantly become red hot. It sometimes melts into small globules of different sizes.

2. If between two slips of window-glasses some gold-leaf be placed, and the slips of glass be pressed firmly together, and the shock from a battery be sent through them, the gold-leaf will be forced into the pores of glass.

3. If the gold-leaf be put between cards, and a strong charge be passed through them, it will be completely fused.

4. Gunpowder may also be fired by the electrical battery.

312. Metallic points attract the electricity from bodies silently, which renders them of a supposed use in defending buildings from *lightning*.

313. When electricity enters at a point, it appears in the form of a star; but when it goes out from a point, it puts on the appearance of a brush.

Obs. Delicate apparatus may be put in motion by the electric fluid when issuing from a point; hence we have *electrical orreries*, *mills*, *&c.*

314. *Lightning* is the rapid motion of vast masses of electric matter, and *Thunder* is the noise produced by the rapid motion of lightning, or electric power.

Obs. As electricity appears to result from the general powers or agencies of matter, it is obvious, that it must be continually exhibited in nature, and that a number of important phenomena must depend upon its operation. When aqueous vapour is condensed, the clouds formed are usually more or less electrical; and the earth below them being brought into an opposite state, by induction, a discharge takes place when the clouds approach within a certain distance, constituting *lightning;* and the undulation of the air, produced by the discharge, is the cause of *thunder*, which is more or less intense, and of longer or shorter duration, according to the quantity of air acted upon, and the distance of the place where the report is heard from the point of its discharge.

315. When the electric fluid passes through highly rarefied air, it constitutes the *aurora borealis*, or *northern lights*. Most of the great convulsions of nature, such as earthquakes, whirlwinds, hurricanes, &c. are generally accompanied by, and often dependent upon, the power of electricity.

Obs. The water-spout is probably the result of the operation of a weakly electrical cloud, at an inconsiderable elevation above the sea, brought into an opposite state; and the attraction of the lower part of the cloud, for the surface of the water, may be the immediate cause of this extraordinary phenomenon. The corruscations of the aurora borealis and australis, precisely resemble strong artificial electricity, discharged through rare air; and as the poles are non-conductors, being coated with ice or snow, and as vapour must be constantly formed in the atmosphere above them, the idea of Franklin is not improbable, that the auroras may arise from a discharge of electricity, accumulated in the atmosphere near the poles, into its rarer parts; though other solutions of the phenomena may be given on the idea, that the earth itself is endowed with electrical polarity; or that the motions of the atmosphere produce the effect.

QUESTIONS ON ELECTRICITY.

What parts of bodies contain the *electric fluid*, internal or external?

Under what circumstances are the effects of the electric fluid shown?

When a piece of sealing-wax, or glass, is rubbed, why does it gain the power of attracting or repelling light bodies?

How is it proved that the electric fluid will pass through a metal?

How is it proved that it will not pass through glass, or sealing-wax?

What substances are *conductors* and what are *non-conductors* of this fluid?

When a surface is supposed to have more than its natural quantity of this agent, what is said of it?

When a surface has less of the fluid how is it distinguished from one which has more?

When is a body said to be *insulated?*

Under what circumstances can the human body be made to give an electric shock?

What are the principal methods of exciting the electric fluid?

When do two electrified bodies repel each other? and when do they attract each other?

How is it shown that when an insulated person rubs a glass tube the person is electrified differently from the tube?

What is meant by *vitreous* and *resinous* electricity?

When electricity is excited by rubbing two surfaces together, are they both in the same electrical states?

What is meant by *electrics?*

What is said of the stone called *tourmalin?*

When two surfaces oppositely electrified are united what is the effect?

Explain the uses of the different parts of the electrical machine.

What is an *electrometer?*

If a surface containing its natural share of electricity be brought near one which is positively or negatively electrified, what is the effect?

Does the electric fluid spread on glass?

How can it be communicated to a part of the surface only?

When is a piece of glass said to be *coated?*

What happens when a communication is made between both sides of a coated and charged glass?

What shaped glasses answer best for these experiments?

What is a *Leyden phial?*

Explain its structure and the method of charging and discharging it?

What constitutes an *electrical battery?*

Mention some of the striking experiments made by the battery.

How are buildings defended from the effects of lightning?

When does electricity appear as a *star,* and when as a *brush?*

How can machinery be put in motion by electricity?

What is *lightning?*

What is *thunder?*

What constitutes the *aurora borealis?*

What is the cause of the *water spout?*

GALVANIC ELECTRICITY.

316. Galvanism is another mode of exciting electricity. In electricity the effects are chiefly excited by mechanical action; but the effects of galvanism are produced by the chemical action of bodies upon each other.

317. The nerves and muscles of animals are most easily affected by the galvanic fluid; but combined in the voltaic battery, it possesses surprising powers of chemical decomposition.

Obs. 1. In 1791, Galvani, of Bologna, discovered that a dead frog may have its muscles brought into action by very small quantities of electricity. He also discovered that the same motions may be produced in the dead animal, merely by making a communication between the nerves, and the muscles, by means of conducting substances.

2. Some fishes have the property of giving shocks analogous to those of artificial electricity; namely, the *torpedo*, the *gymnotus electricus*, and the *silurus electricus*. If the torpedo, whilst standing in water, but not insulated, be touched with one hand, it generally communicates a trembling motion or slight shock to the hand. If the torpedo be touched with both hands at the same time, one hand being applied to its under and the other to its upper surface, a shock will be received exactly like that occasioned by the Leyden phial. The shock given by the torpedo when in air, is about four times as strong as when in water; and when the animal is touched on both surfaces by the same hand, the thumb being applied to one surface, and the middle finger to the opposite, the shock is felt much stronger than when the circuit is formed by both hands. The gymnotus electricus, or electrical eel, possesses all the electric properties of the torpedo, but in a superior degree. When small fish are put into the water wherein the gymnotus is kept, they are generally stunned or killed by the shock, and then they are swallowed if the animal be hungry. The strongest shock of the gymnotus will pass a very short interruption of continuity in the circuit. When the interruption is formed by the incision made by a penknife on a slip of tin-foil that is pasted on glass, and that slip is put into the circuit, the shock, in passing through

that interruption, will shew a small but vivid spark, plainly to be seen in a dark room. The gymnotus seemed also to be possessed of a sort of *new sense*, by which he knows whether the bodies presented to him are conductors or not. This fact has been ascertained by a great number of experiments.

Exp. 1. If a living frog, or a live fish, as a flounder, having a slip of tin-foil pasted on its back, be placed upon a piece of zinc, whenever a communication is formed between the zinc and tin-foil, the spasms of the muscles are excited.

2. If a person place a piece of one metal, as a half-crown, above, and a piece of some other metal, as zinc, below his tongue, by bringing the outer edges of these pieces in contact, he will perceive a peculiar taste, and in the dark will see a flash of light.

3. If a person in a dark place put a slip of tin-foil upon the bulb of one of his eyes, and a piece of silver in his mouth, by causing these pieces to communicate, a faint flash will appear before his eyes.

318. The conductors of the galvanic fluid are divided into the *perfect* and *imperfect*. The *perfect* conductors consist of metallic substances and charcoal.—The *imperfect* conductors are water and oxydated fluids, as the acids, and all the substances that contain these fluids.

319. The simplest galvanic combinations must consist of three different conductors, not wholly of one class. When two of the three bodies are of the first class, the combination is said to be of the first order; when otherwise, it is said to be of the second.

320. It seems to be indispensably requisite, in simple galvanic circles, that the conductors of one class shall have some chemical action upon those of the other.

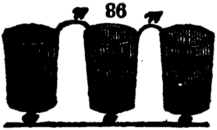
Exp. If a piece of zinc be laid upon a piece of copper, and upon the copper a piece of card or flannel, moistened with a solution of salt water, a *circle* of the first class is formed; and then if three other pieces be laid on these in the same order, and repeated several times, the whole will form a pile or *battery* of the *first* order.

321. When the three bodies which form a galvanic circle of the first order are laid on one another, the up-

per and the under one not touching, these two extremes form opposite electric states.

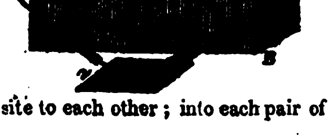
322. The galvanic effects may be increased to any degree, by a repetition of the same simple galvanic combination, and these repeated combinations are called galvanic piles or batteries, which may be constructed of various forms.

Exp. 1. Take a number, say twelve plates of silver, and the same number of pieces of zinc, and also of woollen cloth, the last having been soaked in a solution of sal ammoniac in water; with these a pile is to be formed, viz. a piece of silver, a piece of zinc, a piece of cloth, and thus repeated. These are to be supported by three glass rods placed perpendicularly with pieces of wood at the top and bottom, and the pile is complete, and will afford a constant current of electric fluid, through any conducting substance; thus, if one hand be applied to the lower plate, and the other to the upper one, a shock will be felt, which is repeated as often as the contact is renewed. But the plates will soon become *oxydated*, and require cleaning in order to make them act.



86

2. Another battery consists of a row of glasses of any shape, *a a*, fig. 86, containing a solution of salt and water; into each of these, except the two on the outside, is put a plate of zinc *z*, and another of silver *x*; these plates communicate by means of the wires *w w*, and are so fastened, that the silver, *x*, in one glass is connected with the zinc, *z*, in the other: when one hand is dipped into the first glass, and another in the last, a shock is felt. The glasses may be of any number.



87

3. The most convenient kind of battery consists of a trough B, fig. 87, made of baked wood, three inches broad, and about as deep; in the sides of the trough are grooves opposite to each other; into each pair of grooves is fixed by cement

a plate of zinc and silver soldered together, and in the order of silver and zinc; the cement must be filled in so as to prevent any communication between the different cells. The cells are to be filled with water, or with a solution of water and nitrous acid, when, a communication being made between the first and last cell, by means of the hands, a strong shock is felt, and will be repeated as often as the contact is renewed.

4. Several persons, by joining hands, having first wetted them with water, may receive the shock.

5. If plates of copper and zinc, two or three inches square, and pieces of cloth of the same size, soaked in a solution of salts of sal ammoniac, or nitre, be arranged in the order of copper, zinc, moistened cloth, and so on, and made into an insulated pile, of which the series are two hundred, several remarkable phenomena will occur. When one hand is applied to the bottom of the pile, and the other to the top, both hands being moistened, a shock will be perceived. When a metallic wire, having a bit of well burned charcoal at its extremity, is made to connect the two extremities of the pile, a spark will be perceived, or the point of the charcoal will become ignited. A wire connected with the top of the pile, brought in contact with a sensible electrometer, will cause the leaves to diverge; and, by removing the wire and applying excited glass to the electrometer, it will be found that the electricity is positive; a wire connected with the bottom of the pile will affect it with negative electricity; a wire from the middle of the pile will have no influence on the instrument. If wires of platina from the extremities of the pile be introduced into water, or into two portions of water connected by moist substances, oxygen gas will separate at the wire exhibiting the positive electricity; and hydrogen gas at the wire exhibiting the negative electricity; and the proportions are such, when the proper circumstances exist, that they will produce water when exploded by the electrical spark, that is, the volume of hydrogen will be to that of oxygen, as two to one. If the same wires be introduced into a strong solution of sulphuric or phosphoric acid, or into metallic solutions, oxygen will separate at the positive surface, the inflammable, or metallic matter contained in the solution, at the negative surface.

323. The spark from a powerful galvanic battery acts upon and inflames gunpowder, charcoal, cotton, and other inflammable bodies, melts all metals, disperses diamonds, &c.

Exp. Fill the battery (fig. 87,) with water and nitrous acid, in the proportion of nine parts of water and one of acid, and wipe the edges of the plates very dry, then the wires *w w* are to be fastened to pieces of copper, and put into the outer cells: *a a* are little glass tubes to hold the wires by. Bring the ends of the wires together on the plate of glass *x*, and a spark will be perceived: if gunpowder be laid on the glass between the points of the wires, it will be exploded.

2. Gold and silver leaf may be inflamed in this way; Dutch gold burns with a beautiful green light; silver with pale blue; gold with yellow light.

3. The most powerful combination that exists, in which the greatest number of alterations is combined with extent of surface, is that in the laboratory of the *Royal Institution*. It consists of two hundred instruments, connected together in regular order, each composed of ten double plates arranged in cells of porcelain, and containing in each plate 32 square inches; so that the whole number of double plates is 2000, and the whole surface 128,000 square inches. This battery, when the cells were filled with sixty parts of water, mixed with one part of nitric acid, and one part of sulphuric acid, affords a series of brilliant and impressive effects. When pieces of charcoal about an inch long, and one-sixth of an inch in diameter, are brought near each other, (within the thirtieth or fortieth part of an inch) a bright spark is produced, and more than half the volume of the charcoal becomes ignited to whiteness, and by withdrawing the points from each other a constant discharge takes place through the heated air, in a space equal at least to four inches, producing a most brilliant ascending arch of light, broad, and conical in form in the middle. When any substance is introduced into this arch, it instantly becomes ignited; platina melts as readily in it as wax in the flame of a common candle; quartz, the sapphire, magnesia, lime, all enter into fusion: fragments of diamond, and points of charcoal and plumbago, rapidly disappear and seem to evaporate in it. Such are the decomposing powers of electricity, that not even insoluble compounds are capable of resisting their energy: for glass, sulphate of baryta, fluor spar, &c. when moistened and placed in contact with electrified surfaces from the voltaic apparatus, are slowly acted upon, and the alkaline, earthy, or acid matter carried to the poles in the common order. Not even the most solid aggregates, nor the firmest compounds, are capable of resisting this mode of attack; its operation is slow, but the

results are certain; and sooner or later, by means of it, bodies are resolved into simpler forms of matter.—*Davy.*

324. By galvanism many facts in common life are explained, which were unintelligible before.

Exp. 1. Porter is said to have a peculiar taste when drank out of a pewter vessel; here is a complete galvanic circle of the second order; the moisture of the under lip is one conductor of the second class, the porter is the other, and the pewter is the conductor of the first class.

2. Another galvanic circle is seen by the discolouration of a silver spoon in eating eggs; the saliva and fluid egg are conductors of the second class, and the silver of the first.

3. Pure mercury retains its splendour a long time; but let it be amalgamated with tin, and it is quickly oxydated.

4. Works of metal, the parts of which are soldered together, soon tarnish in the places where the metals are joined.

5. The nails and the copper in the sheathing of ships are soon corroded about the place of contact. These are the effects of galvanism.

325. The effects of galvanism on metallic bodies are greatly increased by using plates of a large size; and on the contrary the shock is increased by multiplying the pairs of plates.

Obs. 1. The shock of a battery containing 80 or 100 pairs of plates, of three or four inches in diameter, is such as few persons would be willing to bear more than once. At the same time, such a battery produces but feeble effects when passed through a metallic wire. On the contrary, if one or two pairs of plates containing the same extent of surface be used, the sensation it gives is hardly to be felt, while it will deflagrate a metallic wire of considerable size.

2. Professor Hare, of Philadelphia, has invented a new galvanic apparatus, in which the calorific influence, or power of deflagration, is immensely increased while the electrical influence is scarcely to be felt.

This instrument is so contrived as to exhibit in effect only two galvanic pairs of enormous size.

In consequence of the phenomena produced by this machine, the inventor has offered a new theory of galvanism, which is likely to form a distinct era in the history of that science. See Silliman's Journal, also the last edition of Henry's Chemistry.

326. There is a remarkable analogy between the

galvanic influence and the nervous influence. The galvanic influence being capable, in some instances of supplying the place of the nerves.

Obs. 1. Dr. Wilson Phillip in his inquiry into the laws of the vital functions has shown, that if a nerve be divided, and a stream of galvanism be directed along and through the part, whose functions depend on this, that the function was performed as usual. Thus on dividing the nerves which are distributed to the stomach, the process of digestion ceases though the animal continues to live for some time. But on supplying the place of the nervous power by the galvanic influence, digestion was performed as usual.

2. In the same way it was found, that when the nerves distributed to other parts were divided, and the part became palsied for want of the nervous power, a stream of galvanism rightly directed would again in a good degree restore the action of that part.

3. Dr. Phillip having conjectured that the heat of animals depended on the influence of the nerves, wished to observe how far the galvanic power might produce this effect. For this purpose some blood was drawn from two animals of the same kind and temperature into two small cups. The blood in one of the cups was submitted to the galvanic influence, while the other was placed under the same circumstances, except in this respect. Now if the galvanized blood remained warm the longest, or had its temperature increased, it would show an additional analogy between the galvanic and nervous energy, if indeed animal heat depends on the latter. The experiment gave a decided proof that the galvanic power had some influence on the temperature of newly drawn blood, for that portion which was submitted to its action, not only remained warm longer than the other, but its temperature was actually raised several degrees.

4. From the difficulty in breathing, which animals experience on depriving the lungs of a portion of their nervous influence, Dr. Phillip was led to make trial of galvanism in *asthma*, suspecting in this disease there might be a want of nervous power. The inference which he draws from a very considerable number of trials on persons afflicted with this disease, is, that there is a difficult transmission of the nervous influence, through the nerves which supply the organs of respiration, and that in a great majority of cases the asthma may be permanently cured, or at least relieved by galvanism.

327. Galvanism has a peculiar and most surprising effect on the muscles of dead animals, their limbs being thrown into violent motion by it a considerable time after the life of the animal is extinct.

5. The most striking effects of galvanism on the human frame after death, were exhibited at Glasgow a few years since.

The subject on which these experiments were made, was the body of the murderer Clydesdale, who was hanged at that city. He was suspended an hour, and the first experiment was made in about ten minutes after he was cut down. The galvanic battery consisted of 270 pairs of four inch plates.

The subject was prepared for the first experiment by making an incision into the nape of the neck, and removing a part of the *atlas vertebre*, so as to bring the spinal marrow into view; at the same time, another incision was made in the left hip so as to lay above the *sciatic* nerve and another small one in the heel. The pointed rod connected with one end of the battery was now made to touch the spinal marrow, while the end of the other was placed in contact with the sciatic nerve. Every muscle of the body was immediately agitated with convulsive movements resembling a violent shuddering from cold. On moving the rod to the heel, the knee being previously bent, the leg was thrown out with such violence, as nearly to overturn one of the assistants, who in vain attempted to prevent its extension.

The next experiment was made by directing the galvanic power in the course of the *phrenic* nerve, which goes to the principal muscle of respiration, the diaphragm. The effects were far more striking than before. "Full, nay, laborious breathing," says Dr. Ure, "instantly commenced. The chest heaved and fell; the abdomen was protruded, and again collapsed with the relaxing and retiring diaphragm."

In the judgment of many scientific gentlemen who witnessed the scene, this respiratory experiment was, perhaps, the most striking ever made with a philosophical apparatus. The next experiment was made by applying one of the wires to the *supra obital* nerve under the eye brow, and the other to the heel. Most extraordinary grimaces were made; "every muscle in the countenance was simultaneously thrown into fearful action; rage, horror, despair, anguish, and ghastly smiles, united their hideous expressions in the murderer's face." At this period, several of the spectators were forced to leave the room from terror or sickness, and one gentleman fainted. "In the last experiment, one of the wires was made to touch the spinal marrow at the nape of the neck, and the other an incision in the top of the fore finger; the first being previously clenched. The finger extended instantly, and from the convulsive agitation of the arm, the finger seemed to point out the different spectators, some of whom thought he had really come to life."

QUESTIONS ON GALVANISM.

What is meant by *Galvanism?*

What parts of animals are most easily affected by the galvanic fluid?

When, and by whom was the galvanic principle discovered?

What effect does it have on dead animals?

What animals have the power of giving electric shocks?

What is the experiment with the living frog, or fish?

How are galvanic conductors divided?

What are the *perfect*, and what the *imperfect* conductors?

What are the most simple galvanic combinations?

When is the combination of the first, and when of the second order?

Do the conductors of one class have any chemical action on those of the other?

How is a battery of the first order constructed?

What parts of a pile are in opposite electric states?

How can galvanic effects be increased?

Explain the mode of constructing a galvanic battery.

What substances can be set on fire by the galvanic shock?

What fluid is used to fill a galvanic trough?

What facts in common life are explained by galvanism?

In what respect is it increased by multiplying the pairs of small plates?

What is Professor Hare's invention?

What analogy is there between galvanism and the nervous influence?

What effect does galvanism have on the temperature of warm blood?

What is said of its effects on asthma?

What is said of the effects of galvanism on the body of Clydesdale?

OF MAGNETISM.

328. Magnetism explains the properties of the loadstone, or natural magnet, which is a dark coloured and hard mineral body, and is found to be an ore of iron, being generally found in iron mines.

The magnetic properties of the natural magnet may be communicated to other bodies, which are then called artificial magnets. These properties can, however, be communicated to no other substances than iron or nickel.

329. The following are the characteristic properties of a magnet. 1. The magnet attracts iron and steel. 2. A magnet, if left at liberty, will point towards the poles of the earth, or very nearly so, and each end always points to the same pole. 3. When the north pole of one magnet is presented within a certain distance to the south pole of another, they will attract each other. But if a north pole of one be presented to the north pole of another, or a south to a south, they will repel each other. 4. The two poles of a magnet, left at liberty, do not lie in the same horizontal direction; one of them *inclines* towards the horizon, and of course the inclination of this causes an elevation of the other pole above it. This is called the inclination or *dipping* of the magnet. 5. Any magnet may be made to impart those properties to iron or steel.

All natural and artificial magnets, as well as the bodies upon which they act, are either iron in its pure state, or such compounds as contain it. All magnets attract iron and nickel.

Obs. 1. The action and re-action of the magnetic power are mutual and equal; for if a piece of iron, or steel, or other ferruginous substance, be brought within a certain distance of one of the poles of a magnet, it is attracted by it, so as to adhere to the magnet, and not suffer itself to be separated without an evident effort.

2. The attraction is mutual, for the iron attracts the magnet as much as the magnet attracts the iron; since if they be placed on pieces of wood or cork, so as to float upon the surface of water, it will be found that the iron advances towards the magnet as well as the magnet advances towards the iron: or, if the iron be kept steady, then the magnet will move towards it.

330. When a magnet is at liberty to move itself freely, it constantly turns the same end towards *the north pole*, and of course the opposite part towards *the south pole*, of the earth.

331. Those parts of the magnet's surface which it turns towards the poles of the earth, are called the north and south poles of the magnet.

332. The property of pointing to these poles is called its *directive power*, and when it moves to place itself in that direction, it is said to *traverse*.

333. The *magnetic meridian* passes through the poles of the magnet when standing in their natural direction. The *declination* of the magnet, or of the magnetic needle, is the angle which *the magnetic meridian* makes with the *meridian of the place*.

334. The north or south poles of two magnets *repel* each other; but the north pole of one *attracts* the south pole of another.

Exp. Place a magnetic needle upon a pin stuck on a table, and when it stands steady, place an iron bar, eight inches long, and half an inch thick, upon the table, so that one end of it may be on one side of the north pole of the needle, and near enough to draw it a little out of its natural direction. In this situation approach gradually the north pole of a magnet to the other extremity of the bar, and you will see the needle's north end will recede from the bar, in proportion as the magnet is brought nearer to the bar.

335. The inclination, or *dipping*, of the magnetic needle, expresses the property which the magnet possesses of inclining one of its poles towards the horizon, and elevating the other pole above it.

336. Any magnet may, by proper methods, be made to impart its properties to iron, steel, or nickel

337. When a piece of iron is brought within a certain distance of one of the poles of a magnet it is attracted by it; the attraction is strongest at the poles.

338. The magnetic attraction is not in the least diminished by the *interposition* of any bodies except iron.

Exp. 1. Suppose a magnet placed at an inch distance from a piece of iron, requires an ounce of force to remove it, or which is the same thing, suppose that the attraction towards each other is equal to one ounce: it will be found that the same degree of attraction remains constantly unaltered, though a plate of other metal, glass, paper, &c. be interposed between the magnet and the iron, or though they be inclosed in separate boxes of glass or other matter.

2. Move steel filings placed on a brass plate, in water, &c. by holding a magnet under the vessel.

3. Strew on a sheet of paper, some iron filings, and lay a small magnet among them; then shake the table a little, and the filings will arrange themselves in the way represented in fig. 90. But if iron filings are shaken through a gauze sieve upon a paper that covers a bar magnet, the filings will be arranged in curved lines.

4. Sprinkle steel dust on a a sheet of paper, under which is placed a magnet, or two magnets, having their poles opposite to each other, and at the distance of about an inch.

5. A needle under an exhausted receiver, will be attracted at the same distance as in the open air.

339. Soft iron is attracted by the magnet more forcibly than steel, but it is not capable of preserving the magnetic property so long.

340. Heat weakens the magnetic power, and a great heat destroys it. The gradual addition of weight to a magnet kept in its proper situation, increases the magnetic power.

Obs. Among natural magnets, the smallest generally possess a greater attractive power, in proportion to their size, than those which are larger. There have been natural magnets not exceeding twenty or thirty grains, which would lift a piece of iron that would weigh forty or fifty times more than themselves. A small magnet, worn by Sir Isaac Newton in a ring, weighing about three grains, is said to have taken up 746 grains, or near 250 times its own weight, and Mr. Cavallo has seen one of six or seven grains weight, which was capable of lifting a weight of 500 grains. But magnets of two pounds and upwards, seldom lift up ten times their own weight of iron.

341. The north pole of a magnet is more powerful in the northern, and the south in the southern parts of the world.

342. When a magnet with two poles is freely suspended, or floats upon water, with no iron near it, it places itself in the magnetic meridian, and it is this principle of polarity that makes it so useful to navigate at sea.

Obs. 1. When a magnet is kept freely suspended, so that it may turn north or south, the pilot, by looking at its position, can steer his course in any required direction at sea.

2. An artificial magnet, fitted up in a proper box, is called the *magnetic needle*, and the whole together is called the *mariner's compass.* See figs. 90, 91.

3. Though the north pole of the magnet always points toward the northern, and the south toward the southern parts, yet their direction is seldom in the exact direction of the poles of the earth, that is, the magnetic and the real meridian seldom coincide, and the angle which they make is called the *angle of declination*, or *variation* of the magnetic needle.

4. This declination is said to be *east* or *west*, according as the north pole of the needle is eastward or westward of the true meridian of the place.

5. At present the declination, or variation, of the magnetic needle, is about twenty-four degrees westward at London, and the dipping seventy degrees.

343. When a piece of iron is brought sufficiently near a magnet, it becomes itself a magnet. Bars of iron that have stood long in a perpendicular situation, are generally found to be magnetical.

Obs. 1. If a long piece of hard iron be made red hot, and then suffered to cool in the direction of the magnetical line, it becomes magnetical. The electric shock will often render iron magnetical; so also will lightning.

2. Artificial magnets are made by applying one or more powerful magnets to pieces of hard steel. The power of a magnet is not diminished by communicating its properties to other bodies.

3. Two or more magnets joined together may communicate

a greater power to a piece of steel than either of them possesses singly.

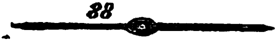
4. The phenomenon of the compass, and the dipping needle, and of the magnetism acquired by an iron bar in a vertical position, leave no room to doubt but that the *cause* exists within the earth. Dr. Halley supposed that the earth has within it a larger magnetic globe, not fixed within to the external parts, having four magnetic poles, two fixed and two moveable, which will account for all the phenomena of the compass and dipping needle. This would make the variation subject to a constant law, whereas we find casual changes which cannot be accounted for upon this hypothesis. This the Doctor supposes may arise from an unequal and irregular distribution of the magnetical matter. The irregular distribution also of ferruginous matter in the shell may likewise cause some irregularities.

5. Mr. Cavallo's opinion is, that the magnetism of the earth arises from the magnetic substances therein contained, and that the magnetic poles may be considered as the centres of the polarities of all the particular aggregates of the magnetic substances; and as these substances are subject to change, the poles will change. Perhaps it may not be easy to conceive how these substances can have changed so materially, as to have caused so great a variation in the poles, the position of the compass having changed from the east towards the west about thirty-three degrees in two hundred years. Also the gradual, though not exactly regular, change of variation shews that it cannot depend upon the accidental changes which may take place in the matter of the earth.

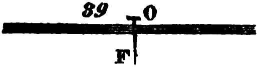
6. Mr. Churchman, of America, says there are two magnetic poles of the earth, one to the north and the other to the south, at different distances from the poles of the earth, and revolving in different times; and from the combined influence of these two poles, he deduces rules for the position of the needle in all places of the earth, and at all times past, present, and to come. The north magnetic pole, he says, makes a complete revolution in 426 years, 77 days, and 9 hours, and the south pole in about 5459 years. In the beginning of the year 1777, the north magnetic pole was 76° 4′ north latitude; and in longitude from Greenwich 140° east; and the south was in 72° south latitude, 140° east from Greenwich.

344. A magnetic needle is made by fastening the steel on a piece of board, and drawing magnets over it, from the centre outwards.

88



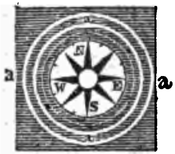
89



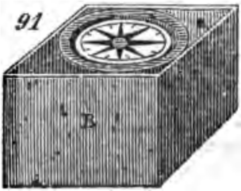
Illus. 1. A magnetic needle is represented in figs. 88 and 89, the first of which shows the upper side, and the second a side view of the needle, having a pretty large hole in the middle, to which a conical piece is adapted by means of a brass piece O, into this the agate cap (as it is called) is fastened. The apex of the hollow cap rests upon the point of a pin F, which is fixed in the centre of the box, and upon which the needle being properly balanced, turns very nimbly.

Illus. 2. A mariner's compass is represented in fig. 90; the box which contains the card, or fly, with the needle, is made of a circular form, either of wood, or brass, or copper. It is suspended within a square wooden box B, fig. 91, by means of two concentric circles, called gambols, so fixed by cross axes, *a*, *a*, *a*, *a*, fig. 90, to the two boxes, that the inner one, or compass box, shall retain an horizontal position in all motions of a ship, whilst the outer or square box is fixed with respect to the ship. The compass box is covered with a pane of glass, that the motions of the card may not be disturbed by the wind. What is called the card is a circular piece of paper, which is fastened upon the needle, and moves with it. The outer edge of this card is divided into 360 equal parts or degrees, and within the circle of these divisions it is again divided into 32 equal parts, or arcs, which are called the points of the compass, or rhumbs, each of which is often subdivided into quarters.

90



91



3. There seems to be a similarity between magnetism and electricity. If two pieces of soft iron wire be led each to a separate thread, and they are hung freely, and if the north end of a magnet bar be brought under them, the wires will repel each other as in electricity. The same result would happen if the south pole of the magnet be presented instead of the north.

QUESTIONS ON MAGNETISM.

What is the *natural magnet*, and where is it found?

To what substances can magnetic properties be communicated?

What are the characteristic properties of the magnet?

What are the substances attracted by the magnet?

What are the poles of the magnet?

What is the *magnetic meridian?*

What is the declination of the magnetic needle?

Which of the magnetic poles *attract*, and which *repel* each other?

What is meant by the dipping of the needle?

Is the attraction of a magnet diminished by the interposition of any body?

How is this proved?

Which is attracted most powerfully, iron or steel?

How is the magnetic power weakened or destroyed?

How is the magnetic power increased?

When does the magnet place itself in the magnetic meridian?

Whas is meant by the *angle of declination*, or variation?

What is a mariner's compass?

In what cases does iron become magnetic without the use of a magnet?

How are artificial magnets made?

Where does the *cause* of magnetism exist?

What is Mr. Cavallo's opinion of the cause of magnetism?

What is Mr. Churchman's opinion?

How is a magnetic needle made?

Explain the figure of the mariner's compass.

GLOSSARY

OF SCIENTIFIC TERMS AND TECHNICAL WORDS.

Accelerated motion, is motion added to motion, by the constant action of an original force.

Acoustics, the science of sound and hearing.

Air-Pump, a machine for making experiments on air.

Amplitude, the point of the compass at which a heavenly body rises or sets.

Aphelion, the point of the orbit of a planet which is the most distant from the sun.

Apogee, the sun's or moon's greatest distance from the earth.

Astronomy, the science which treats of the planets, stars, and celestial motions.

Attraction, the phenomena of bodies falling together, without sensible cause.

Atmosphere, the fluid or air in which men and other animals live, and which surrounds the earth to a considerable height.

Azimuth, the bearing of any heavenly body which is above the horizon.

Barometer, an instrument for measuring the elasticity of the atmospheric air.

Cause, that which produces or appears to produce *an effect*.

Capillary tubes, which resemble hair, and exhibit peculiar phenomena of attraction on fluids.

Central forces, that composition of forces, by which bodies move in circles or curves.

Centripetal force, the force which acts from the circumference towards the centre.

Centrifugal force, the force which acts in the direction of a tangent to the circle or orbit.

Centre of Gravity, the point of any body about which all its parts balance each other.

Cohesion, the power which binds particles of matter into solid masses.

Coats of the eye, the sclerotica, the choroides, and the retina.

Conductors, classes of bodies which conduct, with different degrees of facility, the powers of heat and electricity.

Concave, a hollow surface.

Convex, a projecting surface.

Convergency, tending towards a point.

Constellations, figures which the various groups of stars are supposed to resemble.

Decompose, to take to pieces, or analyze.

Declination, the distance of a heavenly body, north or south of the equinoctial.

Diagonal, the line drawn from one angle to another of any figure.

Disc, the face or surface of the sun or moon.

Divergency, spreading from a point.

Divisibility, the power which exists of dividing particles o matter indefinitely.

Dynamics, the science of motion, forces, or momenta.

Excentricity, in the earth's orbit; the excentricity is equal to 168 ten thousandths, or .0168 of the mean distance.

Excentricity of the planet's orbit, is the distance of the sun from the centre of the orbit.

Ecliptic, the line in which the sun appears to move.

Eclipse of the Sun, an interception of the light of the sun on the earth by the intervening moon.

Eclipse of the Moon, the interception of the light of the sun on the moon by the intervening earth.

Elasticity, the disposition and power which bodies possess of returning to their original position and shape.

Elements, any substances which cannot be decomposed, as oxygen, nitrogen, and hydrogen; phosphorus, sulphur, carbon, and the earths; the metals, and the alkalies.

Equinoctial or *Equator*, the circle of the earth, which is midway between the north and south pole.

Equation of time, arises from various unequal motions of the sun, but chiefly from the quick motion in the earth's perihelion, which is 61′ 10″ per day, on January 1, and the slow motion in the aphelion, which is about 57′ 11 1-2″ per day, or one fifteenth less, on July 1.

Equinoxes, the beginning of Aries and Libra, or equal day and night.

Eudiometer, an instrument for measuring the purity of air.

Evaporation, the passing of fluids into a state of vapour.

Focus, a central point, the place where rays of light or a natural power converge. Its plural is *foci*.

Fulcrum, a prop on which a lever acts.

Fusion, the rendering of a solid body fluid, by the application of heat.

Gas, the elastic or expanded state of any fluid or substance formed by the action of heat.

Galvanism, the science of chemical or animal electricity, in which electrical effects are permanent without friction.

Geocentric place, the places of the planets, as seen from the earth.

Gravity, the tendency of masses of matter to fall together.

Gravity, specific, the relative weight of different bodies in regard to some standard, as water.

Heliocentric place, the places of the planets as seen from the sun.

Horison, the line that bounds the view, where the earth and heavens seem to meet, and which cuts the heavens into two equal parts.

Humours of the eye, the aqueous, the crystalline, and the vitreous.

Hydrostatics, the science which teaches the laws of pressure and motion in fluids.

Hydraulics, the science which teaches the construction of water engines.

Hydrogen, the bases of water, 15 parts with 85 of oxygen, forming 100 parts of water, and combined with carbon, it produces the gas lights.

Hydrogen gas, the same as inflammable air, and fourteen times lighter than atmospheric air.

Inertness, the disposition which all matter has to remain in its actual state.

Infinite space, a description applied to space; because no bounds or limits can be conceived to it.

Inverse, contrary-wise, an opposite proportion.

Incidence, the point at which a ray of light strikes the surface of any body.

Jar, electrical, formed so as to condense the electric power.

Latitude of places on the earth, is their distance in degrees from the equator, northward or southward.

Latitude, in astronomy is the distance of a heavenly body in degrees from the ecliptic, northward or southward.

Lens, the name of any transparent body, the sides of which are convex or concave, for the purpose of converging or diverging rays of light.

Light, the affection or power by which distant objects are brought in contact with the eye, either by particles in rapid motion, or by vibrations of a universal medium.

Liquid, a state of substance in which, by the accession or powers of heat, the particles slide easily among one another; without heat, all liquids become fixed or solid.

Longitude of places on the earth, is the distance of the meridian of the place from the first meridian, east or west.

Longitude, in astronomy, is the distance of a heavenly body from the beginning of Aries measured on the ecliptic.

Matrix, the substance in which metallic ores are imbedded.

Matter, the basis of all substances, constantly changing its forms, but always maintaining its existence.

Magnetism, the science which treats of the phenomena of the load-stone.

Mechanical Powers, instruments for adding to animal force, as the lever, pulley, wedge, screw, &c.

Menstruum, any liquid which dissolves and acts chemically on any solids.

Meridian, a line passing from the north pole to the south pole, through the zenith of any place.

Metals are distinguished by their weight, splendour, and ductility, and modern chemistry has detected nearly forty kinds, of which platina, the heaviest, is 23 times heavier than water.

Microscope, any instrument by means of which an object, or its true image, may be seen much nearer, and consequently much larger.

Mirror, a reflecting surface, *plane*, *concave*, or *convex*, by means of which bodies may be seen of the natural, of an enlarged, or of a diminished size.

Mobility, the power of moving matter by a sufficient force, under certain laws of motion.

Momentum, the force acquired by different masses of matter, moved with different velocities.

Nadir, the point under foot, opposite the zenith.

Node, the point of a planet's orbit at which it crosses the ecliptic, or earth's orbit.

Non-Conductors, surfaces of bodies which do not receive and transmit the electric power.

Obliquity, of the ecliptic, is the angle made by the plane of the earth's orbit and the equator, in 1813, 23° 27 1-2'.

Opacity, non-transparency.

Optics, the delightful science which treats of the laws of vision, light, and colours.

Parallax, horizontal, the angle which the earth's semi-diameter subtends at a distant heavenly body.

rallax, annual, the angle which the earth's orbit subtends to distant heavenly bodies.

Perihelion, the place in a planet's orbit nearest to the sun, constantly in progression.

Petrifaction, the depositing of earthy matter, from water, on the surface of leaves, and other substances, forming an earthy or stony encrustation.

Pendulums, heavy bodies suspended from a point, and performing vibrations backward and forward.

Physics, the science of matter and bodies, in the abstract.

Plenum, space filled with matter, sensible or insensible to man.

Pneumatics, the science which treats of the properties of air.

Powers opposing, elasticity producing expansion; and gravitation, producing compression.

Prism, a glass wedge, used to refract light, and separate its different rays of colours.

Projectiles, bodies thrown into the air, having a parabolic motion.

Rays, chemical, those of the violet end of the spectrum.

Rainbow, an effect produced by the reflection and refraction of light on drops of rain.

Rarefaction, expansion, dilatation, increase of bulk.

Ray of light, a single beam or impulse of light, sometimes called a pencil of light.

Radius, the line which extends from the centre to the circumference of a circle.

Radius-Vector, the line which extends from the solar centre of the ecliptical orbits of the planets, to the circumference of the orbit; and the areas described by the radius-vector are proportioned to the times, in which they are described.

Repulsion, an opposite power to that of attraction, exerted at very short distances,

Reflection of rays of Light, is their rebounding on striking a polished surface, which they always leave with the same inclination or angle as that with which they fell on it.

Refraction of rays of Light, is the new direction which they receive on passing out of one medium into another.

Retina, is the net of nerves which is spread at the back of the eye to receive the excitement of the rays of light.

Saturation, when a fluid will hold no more of any substance in solution.

Satellites, moons attached to planets,

Secular Motion, the motion in a century.

Sine, the line drawn from the circumference of a circle, perpendicularly on its diameter, being half the chord of double the arch.

Sine, versed, the part of the diameter intercepted by the said perpendicular, and the centre of the circle.

Solidity, the power of all matter to maintain its own space.

Solstices, the beginning of Cancer and Capricorn, or the longest and shortest day.

Spectrum, the oblong image of light made by a prism divided into the seven colorific rays, into calorific rays, and into chemical rays.

Steatite, or *Soap Rock*, a soapy-feeling stone, composed of magnesia, silex, and clay.

Synthesis, the composition, re-union, or re-generation, of any compound.

Syzygies, the moon's place, when the earth, sun, and moon, are in a straight line.

Tangent, a line touching a circle at one point.

Telescope, an arrangement of lenses or mirrors, by which the observer is enabled to see an image of an object, under a larger angle, than he could with the naked eye.

Thermometer, an instrument to discover the heat of bodies, from many degrees below freezing to that of boiling water or 212°.

Vacuum, a space unoccupied by sensible matter.

Vapours, the minute particles of fluids separated by heat and floating in the air.

Velocity. the space which any body moves through in a given time.

Vibration, the action of a musical string, or of the elastic surfaces of bodies when struck.

Volatile, the disposition of bodies to evaporate.

Zenith, the point over head.

Zodiac, a space in the heavens, extending eight degrees on each side of the ecliptic within which space the sun, moon, and planets, move.

Zone, spaces on the earth's surface in which distant phenomena appear, in regard to the seasons and length of days.

N. B. *So many definitions are given in the course of the volume, that it is unnecessary to extend this glossary to all the terms used in the sciences.*

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